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EFFECTS OF AERATION ON GROWTH AND PRODUCTION OF CARPS IN CHITWAN, NEPAL

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ABSTRACT

An experiment was conducted to assess effects of aeration on water quality and yield of carps at farmer's pond of Kathar, Chitwan, Nepal for 225 days from 25 May 2018 to 10 January 2019. Experiment included three treatments: T₁ - No aeration (control), T₂ - 4 hours aeration (4:00 - 8:00 am) and T₃ - 6 hours aeration (4:00 - 10:00 am) with four replications of each. Ponds were stocked with fingerlings of rohu (*Labeo rohita*), mrigal (*Cirrhinus mrigala*), common carp (*Cyprinus carpio*), silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Aristichthys nobilis*) and grass carp (*Ctenopharyngodon idella*) in the ratio of 5:5:4:3:2:1 at a combined stocking density of 10,000 fingerlings/ha. Treatment T₂ and T₃ ponds were provided with a 1 HP paddle wheel aerator. Fish were fed once on the alternate day with locally prepared pellet feed containing 18 % CP at the rate of 2% of body weight. Dissolved oxygen was significantly higher ($p < 0.05$) in aerated ponds than control ponds. The combined gross yield and net yield of carps in aerated ponds was significantly higher ($p < 0.05$) than control ponds. Net profit was 37.7% and 34.2% higher in T₂ and T₃ respectively than T₁. Hence aeration can increase the growth and production of carps by improving dissolved oxygen content in pond water.

Keywords: Carp, aeration, dissolved oxygen, yield

INTRODUCTION

Aquaculture production in Nepal is mostly based on low-input systems relying on low protein agricultural by-products and pond fertilizers. Such resources are also used by agriculture and animal husbandry. Competition for scarce natural resources has recently compelled to promote the development of intensive aquaculture. The intensive aquaculture aims to maximize carrying capacity which is often limited by hydraulic, chemical, physical, and biological parameters (Boyd 1982; Inglis et al. 2000). Increasing the carrying capacity of fish production increases fish and feed loads, thereby increasing oxygen demand and often requires the use of supplemental oxygen in water particularly during morning hours. The low oxygen content disadvantageously influences both the food intake and the utilization of food while anoxia causes fish kills in fertilized ponds during summer conditions (Collins 1994). In heavily stocked and artificially fed fishponds, many problems like organic pollution, deficiency of oxygen, increased level of free carbon dioxide and total increase in ammonia-nitrogen frequently occur. Aeration is a better way to get rid of them (Agarwal 1999; Boyd 1995) by oxidizing ammonia to nitrate and volatilizing the ammonia.

Effective dissolved oxygen (DO) management is essential for high-density aquaculture systems. Mayer et al. (1973), and Tiemeirer and Deyoe (1973) proved that emergency or partial aeration is best technique for preventing fish kills during dissolved oxygen crisis. Aeration in ponds have been

found to increase fish production reducing stratification and causing greater soluble nutrient availability, decreasing organic accumulation at the bottom (Parker and Suttle 1987) and improving water quality (Loyacano 1974; Singh et al. 1980; Hollerman and Boyd 1980; Pawar et al. 2009). Fish always show high feed efficiency when they are fed at required DO in water (Boyd 1998). Carp polyculture is the major fish production system in Nepal and accounts for 90% of aquaculture production. However, carp productivity is low (DoFD 2018). Hence, present study attempts to determine effects of aeration on growth and yield of carps (rohu *Labeo rohita*, mrigal *Cirrhinus mrigala*, silver carp *Hypophthalmichthys molitrix*, bighead carp *Aristichthys nobilis*, grass carp *Ctenopharyngodon idella* and common carp *Cyprinus carpio*), on water quality and gross margin.

MATERIALS AND METHODS

The experiment was conducted in 12 farmer's ponds of $640 \pm 62 \text{ m}^2$ ($380\text{-}900 \text{ m}^2$) area and 1.0 m in depth in Kathar, Chitwan, Nepal for 225 days from 25 May 2018 to 10 January 2019. The experiment was laid in a Completely Randomized Design (CRD) with 3 treatments and 4 replications. The treatments included: T₁ - no aeration (control); T₂ - 4 hours aeration (4 am-8 am); T₃ - 6 hours aeration (4 am-10 am).

All the experimental ponds were completely drained for about 2 weeks before the stocking of fingerlings. Immediately after draining, hydrated lime (Ca(OH)_2) was applied to each pond at the rate of 5 kg/100 m². The ponds were kept dried for 2-3 days after liming and then filled with canal water. Then, the ponds were fertilized at the rate of 4 kg N/ha/day and 1 kg P/ha/day (Knud-Hansen and Pauotong 1993).

Fingerlings of all carps rohu, mrigal, silver carp, bighead carp, grass carp and common carp were obtained from the private hatchery in Chitwan, and stocked in the experimental ponds after a week of initial fertilization. The ponds were stocked with fingerlings of rohu (25%), mrigal (25%), common carp (20%), silver carp (15%), bighead carp (10%) and grass carp (5%) at a combined density of 10,000 fish/ha. Stocking size of fingerlings of rohu, mrigal, silver carp, bighead carp, grass carp and common carp was $2.1 \pm 0.1 \text{ g/fish}$, $2.5 \pm 0.2 \text{ g/fish}$, $3.5 \pm 0.4 \text{ g/fish}$, $4.9 \pm 0.3 \text{ g/fish}$, $3.6 \pm 0.3 \text{ g/fish}$ and $3.3 \pm 0.3 \text{ g/fish}$, respectively.

Two paddle wheel aerators of 1 HP were installed singly in the treatment T₂ and T₃ ponds after 2 weeks of stocking of fingerlings. No aerators were installed in the control pond. T₂ ponds were aerated daily in the morning for 4 hours (4 am - 8 am). Similarly, T₃ ponds were aerated daily in morning for 6 hours (4 am - 10 am).

For the proper maintenance of fertility in the ponds, the experimental ponds were fertilized weekly using urea and DAP at the rate of 470 g/100 m²/week and 350 g/100 m²/week respectively. The frequency of fertilization was determined based on the basis of visual observation of pond fertility status.

Canal water was supplied to ponds to compensate the losses due to evaporation and seepage. Average water depth of about 1.0 m was maintained in each pond throughout the experimental period. A wooden gauge was fixed in the middle of each pond to measure the water depth.

Pellet feed containing 18% protein was locally prepared by mixing rice bran, maize flour, mustard oil cake and soybean cake in the proportion of 2:2:1:1 respectively. Fish were fed once on the alternate day between 8-9 am at the rate of 2 % of the total body weight of fish. Proximate analysis of prepared feed was carried out to determine the dry matter (DM), crude protein (CP), total ash

(TA) and nitrogen free extract (NFE) using the methods of prescribed in AOAC (1990) in aquaculture lab of AFU.

Feeding tray was used in each experimental pond for confined feeding. Feeding ration was adjusted monthly on the basis of fish sampling weight.

For monthly sampling at least 10% of each fish species were netted out and weighed to determine the growth. Fish mortality was also recorded on monthly basis based on farmers' and researcher's observation. Final harvesting of fish was done by draining each pond completely. Harvested fish were weighed individually and in batches by using the electronic and physical balance. Harvested fishes were counted species wise and their batch weight was recorded separately.

Water quality parameters such as water temperature, transparency, DO and pH values were recorded in situ weekly using thermometer (Lutron TM-936 model), Secchi disk, DO meter (Lutron DO-5509 model) and pH (Lutron YK-21 PH model meter) respectively at 6-8 am at the depth of 20 cm. Water samples were collected fortnightly from each pond using the plastic column sampler at 6-8 am for the analysis of total ammonium nitrogen (TAN), nitrite nitrogen ($\text{NO}_2\text{-N}$) and soluble reactive phosphorus (SRP) following APHA (2012).

Gross margin analysis was done by deducting variable costs from income of fish. Variable costs were calculated based on the current market price of materials used in ponds. Similarly, income from the fish sale was calculated at the farm gate price of harvested fish. Average market prices of carp fingerlings were NRs. 1.5-2.5/piece. Similarly, market prices of lime, urea, DAP and feed were NRs. 20, 22, 54 and 25/kg respectively.

Statistical analysis of data was performed by the one-way analysis of variance (ANOVA) using the SPSS statistical software package followed by Duncan's multiple range test. Differences were considered significant at 95% confidence level ($p<0.05$). All means were given with standard error (S.E).

RESULTS

Fish growth

Final mean weight, final total weight, daily weight gain, gross fish yield (GFY) and net fish yield (NFY) of all carps were significantly ($p<0.05$) higher in aerated treatments (T_2 and T_3) than in the control (Table 1). However, there was no significant ($p>0.05$) difference between 4 hours aeration and 6 hours aeration treatments.

Table 1: Growth and yields of carps in different treatments during experimental period (mean $\pm$ SE)

Parameter	T_1	T_2	T_3
	Rohu		
Initial total weight (g /100m ²)	46.9 $\pm$ 3.7 ^a	51.87 $\pm$ 3.44 ^a	46.87 $\pm$ 6.9 ^a
Initial mean weight (g/fish)	1.87 $\pm$ 0.14 ^a	2.07 $\pm$.13 ^a	1.87 $\pm$ 0.27 ^a
Final total weight (kg/100 m ²)	2.23 $\pm$ 6.2 ^b	3.28 $\pm$ 6.1 ^a	3.41 $\pm$ 5.5 ^a
Final mean weight (g/fish)	106.2 $\pm$ 3.15 ^b	149 $\pm$ 3.03 ^a	155.07 $\pm$ 4.6 ^a
Daily weight gain (g/fish/day)	0.47 $\pm$ 0.01 ^b	0.66 $\pm$ 0.01 ^a	0.69 $\pm$ 0.02 ^a
Survival (%)	85.7 $\pm$ 1.28 ^a	88.8 $\pm$ 1.65 ^a	88.8 $\pm$ 1.6 ^a
GFY (t/ha/yr)	0.36 $\pm$ 0.01 ^b	0.53 $\pm$ 0.01 ^a	0.55 $\pm$ 0.02 ^a
NFY (t/ha/yr)	0.35 $\pm$ 0.01 ^b	0.52 $\pm$.01 ^a	0.55 $\pm$ 0.02 ^a

Parameter	T ₁	T ₂	T ₃
Mrigal			
Initial total weight (g /100m ²)	63.2±6.3 ^a	65.6±4.8 ^a	55.6±5.5 ^a
Initial mean weight (g/fish)	2.53±0.25 ^a	2.63±.19 ^a	2.23±.221 ^a
Final total weight (kg/100 m ²)	2.41±1.41 ^b	3.82 ±8.1 ^a	4.05±2.7 ^a
Final mean weight (g/fish)	114.5±4.96 ^b	174.1±3.66 ^a	182.1±5.32 ^a
Daily weight gain (g/fish/day)	0.51±0.02 ^b	0.77±0.02 ^a	0.81±0.02 ^a
Survival (%)	86.4±1.3 ^a	87.59±1.87 ^a	88.67±.5 ^a
GFY (t/ha/yr)	0.39±0.02 ^b	0.62±0.01 ^a	0.65±0.02 ^a
NFY (t/ha/yr)	0.39±0.02 ^b	0.62±0.01 ^a	0.64±0.02 ^a
Silver carp			
Initial total weight (g /100m ²)	55±3.16 ^a	52.37±5.56 ^a	57.7±6.04 ^a
Initial mean weight (g/fish)	3.7±0.21 ^a	3.5±0.36 ^a	3.85±0.4 ^a
Final total weight (kg/100 m ²)	2.37±0.07 ^b	2.68±0.44 ^a	2.7±0.4 ^a
Final mean weight (g/fish)	198±4.9 ^b	223.4±3.7 ^a	228.5±2.9 ^a
Daily weight gain (g/fish/day)	0.88±0.02 ^b	0.99±0.02 ^a	1.02±0.01 ^a
Survival (%)	83±1.4 ^a	83.9±0.91 ^a	84.6±1.04 ^a
GFY (t/ha/yr)	0.39±0.01 ^b	0.43±0.01 ^a	0.44±0.01 ^a
NFY (t/ha/yr)	0.38±0.01 ^b	0.43±0.01 ^a	0.44±0.01 ^a
Bighead carp			
Initial total weight (g /100m ²)	49.68±3.32 ^a	42.9±1.8 ^a	43.5±1.9 ^a
Initial mean weight (g/fish)	4.95±0.33 ^a	4.27±0.16 ^a	4.35±0.19 ^a
Final total weight (kg/100 m ²)	1.94±0.07 ^b	3.2±0.01 ^a	3.5±0.05 ^a
Final mean weight (g/fish)	216.2±8.2 ^b	363.3±6.2 ^a	392.1±6.6 ^a
Daily weight gain (g/fish/day)	0.96±0.04 ^b	1.61±0.07 ^a	1.74±0.03 ^a
Survival (%)	86.3±0.63 ^a	85.3±0.96 ^a	86.22±0.91 ^a
GFY (t/ha/yr)	0.32±0.01 ^b	0.53±0.01 ^a	0.57±0.01 ^a
NFY (t/ha/yr)	0.31±0.01 ^b	0.52±0.01 ^a	0.57±0.01 ^a
Grass carp			
Initial total weight (g /100m ²)	18.24±1.31 ^a	18.3±1.48 ^a	16.8±2.05 ^a
Initial mean weight (g/fish)	3.65±0.29 ^a	3.65±0.29 ^a	3.37±0.41 ^a
Final total weight (kg/100 m ²)	1.36±0.02 ^b	1.76±0.02 ^a	1.82±0.02 ^a
Final mean weight (g/fish)	342 ±3.13 ^b	441.08±6.65 ^a	457.13±6.6 ^a
Daily weight gain (g/fish/day)	1.41 ±0.01 ^b	1.82±0.03 ^a	1.89 ±0.02 ^a
Survival (%)	78.9±1.98 ^a	81.6±0.56 ^a	82.9±1.25 ^a
GFY (t/ha/yr)	0.22±0.001 ^b	0.27±0.001 ^a	0.31±0.001 ^a
NFY (t/ha/yr)	0.22±0.01 ^b	0.27 ±0.01 ^a	0.31±0.01 ^a
Common carp			
Initial total weight (g /100m ²)	66.96±6.59 ^a	61.33±5.27 ^a	51.5±4.11 ^a
Initial mean weight (g/fish)	3.35±.032 ^a	3.05±.26 ^a	2.58±.21 ^a
Final total weight (kg/100 m ²)	3.4±0.1 ^b	6.2±0.06 ^a	6.5±0.64 ^a
Final mean weight (g/fish)	199.2±6.5 ^b	349.9±3.77 ^a	362.1±3.5 ^a
Daily weight gain (g/fish/day)	0.88 ±0.01 ^b	1.01±0.03 ^a	1.01 ±0.01 ^a
Survival (%)	86.5±.63 ^a	89.4 ±0.8 ^a	89.6±1.01 ^a
GFY (t/ha/yr)	0.56±.01 ^b	1.01±.01 ^a	1.05±.03 ^a
NFY (t/ha/yr)	0.54±.01 ^b	1.01±.01 ^a	1.04±0.03 ^a

Mean value with the same superscript in the same row are not significantly different at $p < 0.05$.

Combined gross and net yields of carps

Combined final total weight, total weight gain, gross and net yields of carps were significantly ($p<0.05$) higher in aerated treatments than the control (Table 2).

Table 2: Combined gross and net yields of carps in different treatments during experimental period (mean $\pm$ SE)

Parameter	Treatments		
	T1	T2	T3
Initial total weight (kg/100 m ²)	0.30 $\pm$ 0.07 ^a	0.29 $\pm$ 0.06 ^a	0.27 $\pm$ 0.06 ^a
Final total weight (kg/100 m ²)	13.71 $\pm$ 0.26 ^b	20.94 $\pm$ 0.12 ^a	21.98 $\pm$ 0.34 ^a
Total weight gain (kg/100 m ²)	13.41 $\pm$ 0.20 ^b	20.65 $\pm$ 0.15 ^a	21.71 $\pm$ 0.41 ^a
Gross fish yield (t/ha/yr)	2.24 $\pm$ 0.12 ^b	3.39 $\pm$ 0.15 ^a	3.57 $\pm$ 0.15 ^a
Net fish yield (t/ha/yr)	2.19 $\pm$ 0.12 ^b	3.37 $\pm$ 0.15 ^a	3.55 $\pm$ 0.14 ^a
Survival (%)	84.5 $\pm$ 1.2 ^a	86.1 $\pm$ 1.2 ^a	86.9 $\pm$ 1.1 ^a
AFCR	2.4 $\pm$ 0.0 ^a	2.2 $\pm$ 0.0 ^a	2.2 $\pm$ 0.0 ^a

Mean value with the same superscript in the same row are not significantly different at $p<0.05$.

Water quality

Among the water quality parameters, dissolved oxygen showed significant differences with aeration (Table 3). Aerated ponds (T₂ and T₃) had higher DO in compare with non-aerated ponds T₁ ($p<0.05$). The DO in the control pond remained low in compare with the aerated pond throughout the experimental period. The mean DO was same between T₂ and T₃.

Table 3: Water quality parameters during experimental period (mean $\pm$ SE)

Parameter	Treatments		
	T ₁	T ₂	T ₃
Temperature (°C)	25.5 $\pm$ 0.3 ^a (13.2-33.1)	23.6 $\pm$ 0.2 ^a (12.6-33.1)	23.6 $\pm$ 0.1 ^a (12.5-33.2)
pH	7.1 (6.8-8.1)	7.9 (7-8.8)	8.1 (7.2-8.8)
DO (mg/L)	2.3 $\pm$ 0.8 ^b (1.8-3.2)	6.3 $\pm$ 0.2 ^a (5.1-8.1)	6.1 $\pm$ 0.2 ^a (4.9-8.1)
Secchi depth (cm)	33.5 $\pm$ 2.1 ^a (19-48)	33.3 $\pm$ 1.6 ^a (18-48)	33.6 $\pm$ 1.5 ^a (19-47)
TAN (mg/L)	0.14 $\pm$ 0.01 ^a (0.05-0.26)	0.13 $\pm$ 0.09 ^a (0.02-0.15)	0.09 $\pm$ 0.00 ^a (0.02-0.14)
SRP (mg/L)	0.06 $\pm$ 0.04 ^a (0.01-0.09)	0.03 $\pm$ 0.02 ^a (0.01-0.04)	0.03 $\pm$ 0.01 ^a (0.01-0.04)
Nitrite-nitrogen (mg/L)	0.14 $\pm$ 0.09 ^a (0.05-0.24)	0.18 $\pm$ 0.01 ^a (0.07-0.38)	0.18 $\pm$ 0.01 ^a (0.08-0.38)

Mean value with the same superscript in the same row are not significantly different at $p<0.05$.

Gross margin

Gross margin analysis showed that all treatments produced positive gross margin (Table 4) with highest gross margin in T₂, intermediate in T₃ and lowest in T₁ ($p<0.05$). Gross return was significantly ($p<0.05$) higher in treatments T₂ and T₃ than in the control T₁ due to higher fish yields

in aerated ponds. However, total variable costs were significantly ($p<0.05$) lower in the control T_1 , intermediate in T_2 and highest in T_3 due to lower feed cost and aeration cost.

Table 4: Gross margin analysis (NRs/100 m²) of different treatments in 225 days culture period (mean $\pm$ SE)

Parameter	Treatments		
	T1	T2	T3
Gross return			
Value of fish	3352 $\pm$ 71 ^b	5170 $\pm$ 53 ^a	5550 $\pm$ 85 ^a
Variable costs			
Fingerlings	350 $\pm$ 0 ^a	350 $\pm$ 0 ^a	350 $\pm$ 0 ^a
Lime	150 $\pm$ 0 ^a	150 $\pm$ 0 ^a	150 $\pm$ 0 ^a
DAP	378 $\pm$ 0 ^a	378 $\pm$ 0 ^a	378 $\pm$ 0 ^a
Feed	724 $\pm$ 37 ^b	1115 $\pm$ 14 ^a	1171 $\pm$ 12 ^a
Electric cost	0	756 $\pm$ 0 ^a	1150 $\pm$ 0 ^a
Total variable cost	1602 $\pm$ 41 ^c	2749 $\pm$ 16 ^b	3199 $\pm$ 13 ^a
Gross margin	1750 $\pm$ 36 ^c	2421 $\pm$ 41 ^a	2353 $\pm$ 82 ^b

Mean value with the same superscript in the same row are not significantly different at $p<0.05$.

DISCUSSION

Carp growth and yield

There were significant ($p<0.05$) differences in mean harvest weight, daily weight gain, GFY and NFY of carps between non-aerated and aerated treatments. All growth parameters and yields were better in aerated treatment ponds than control ponds ($p<0.05$) due to higher DO content increased by aeration. Mean growth rates of common carp, rohu, mrigal, bighead carp, silver carp and grass carp in aerated ponds were 32%, 18%, 30 %, 34%, 35% and 27 % higher than in non-aerated ponds. All the carps showed significantly better growth in aerated ponds being enriched with DO in the pond water due to operation of aerators in compare with non-aerated ponds as obtained by Das et al. (2004) with the respective mean growth rates in catla, rohu, mrigal, silver carp, grass carp and puntius in aerated ponds.

The combined gross and net fish yields in aerated ponds were significantly higher than in non-aerated ponds ($p<0.05$). These results showed that growth performance of carps was better in aerated ponds (Jena 1998; Mayer et al. 1973). The combined GFY for T_1 , T_2 and T_3 was 2.24 t/ha/yr, 3.39 t/ha/yr and 3.57 t/ha/yr respectively which was less than current fish productivity in Nepal (CFPCC, 2019). This was due to small stocking size of fingerlings and lower feeding rate of 2%. Moreover, feeding was done in alternate days which might have led to nutrient deficiency and supplementary feed protein level was also low (18% CP). . Similarly, the combined NFY remained 2.19 t/ha/yr, 3.37 t/ha/yr and 3.55 t/ha/yr respectively for T_1 , T_2 and T_3 . Jena (1998) reported 1.5 times more production in presence of aeration when stocking density was 20,000 and 30,000 fingerling/ ha. Present study showed that net fish yield in ponds aerated for 2 hours daily was about 53.9% and ponds aerated for 4 hours daily was 62.1% higher than that of control. This result is supported by findings of Lai-Fa and Boyd (1988) which reported 31.5% higher fish production in an aerated pond and Das et al. (2004) that reported 42.8% a higher production in fish pond fitted with mechanical aeration. The increase in the fish yield can be attributed to the improvement in water quality parameters as suggested by forementioned literatures.

The overall survival of all species ranged between 84.5-86.9 %, which showed that fish survival was not affected by the operation of aerators in the pond. Hollerman and Boyd (1980) reported 92% survival in aerated ponds and 40% survival in non-aerated ponds in Channel Catfish ponds. Similarly, Qayyum et al. (2005) found 64% survival with partial aeration and 21% without aeration in ponds stocked with rohu, mrigal, bighead carp and grass carp at relatively low density of 6270 fish/ha.

Apparent food conversion ratio (AFCR) in present study remained relatively lower due to lower CP (18%) containing feed, 2 % body weight feeding and alternative feeding. AFCR in aerated ponds was 2.2 while in non-aerated pond 2.4 which was similar to the results obtained by Lai-fa and Boyd (1988). Relatively low AFCR obtained in the aerated ponds of this research compared to non-aerated ponds might be due to proper feeding, controlled condition, differences in DO content due to aeration facilities since fish growth, feed efficiency and FCR were affected by DO availability and fish always showed good feed efficiency and low FCR when fed at required DO in water (Bergheim et al. 2006; Duan et al. 2011).

Water quality

Water quality parameters remained within a suitable range for carp production except DO. Dissolved oxygen content was lower in control ponds. Water quality parameters except DO did not differ significantly ($p>0.05$) among treatments. Dissolved oxygen in aerated ponds was significantly higher than in the non-aerated ponds. DO ranged from 1.8-3.2 mg/L for T_1 , 5.1-8.0 mg/L for T_2 and 4.9-8.1 mg/L for T_3 respectively which was more or less similar to the result of Qayyum et al. (2005) which recorded DO ranging from 2-6 mg/L and 4-9 mg/L in non-aerated and aerated ponds, respectively. The higher DO content in the aerated ponds in this research might be due to proper and continuous periodical aeration from paddle wheel aerators as reported by (Debnath et al. 2014). The highest DO of aerated ponds of this research was 8.1 mg/L which was about 2.5 times higher than non-aerated ponds. Dissolved oxygen did not differ between 4 hours and 6 hours aeration which indicates that late morning aeration was not necessary. Due to oxygen production from photosynthesis in the late morning oxygen level was equally higher in 4 hours aeration ponds. Vigorous aeration might have inhibited photosynthesis in 6 hours aerated ponds. Higher DO level in 6 hours aeration ponds was probably from aeration rather than contributed from photosynthesis.

Water was clear and less turbid during the experimental period. The transparency values recorded in this research were within the productive range as aeration does not increase the mud turbidity. The increased deposition of fish excreta, mineralization of organic manure and leftover supplementary feed might have led to build up of metabolites in the pond. As a result, the nitrogenous by-products such as total ammonia, nitrite and soluble reactive phosphorus progressively increased in the ponds (Jena 1998). Boyd and Pillai (1984) reported nitrite-nitrogen levels above 1.0 mg/L in pond water to be fatal for fish culture. Similarly, ammonia and nitrite are more toxic at low oxygen level (Tilak et al. 2002). Consequently, their long-term effect on fish coupled with stress due to low DO would have contributed for the observed lower growth in fish in control ponds.

Gross margin

Income in the present study was solely from carp sales which varied with yields among treatments. Cost estimation was based on the local prices of fertilizer, lime, feed and electricity charge. Results showed that all treatments produced positive net returns. Cost benefit analysis showed that the aerated ponds generated more net profit which were 38.4% and 34.1% higher in T_2 and T_3 as compared with the non-aerated pond T_1 . Higher gross margin in 4 hours aeration treatment was due to lower consumption of electricity and higher carp yield. Lower electricity consumption reduced

variable cost while higher fish yield increased income from fish sale. Lai-Fa and Boyd (1988) reported dissolved oxygen dynamics, aerator performance data and price information in channel catfish ponds and estimated 20% to 25% increase in profit for supplemental aeration which is comparable with this research. This research showed the late morning supplementation of aeration in pond is not as effective and more costly compared with early morning aeration.

CONCLUSION

Present study examined the effects of aeration on water quality, production of carp and gross margin in carp polyculture system of Nepal. Supplementation of aeration significantly increased dissolved oxygen in pond water and improved water quality for the growth of carp. Thus, the supplementation of aeration in ponds increased the total carp yield with better economic returns. Moreover, 4 hours aeration is sufficient to increase fish production compared to 6 hours of aeration daily which increased the total variable cost by extra energy consumption. Thus, 4 hours daily aeration in carp polyculture in morning hours could be beneficial in terms of increasing the fish yield and gross income.

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REFERENCES

- Agarwal, V.P. (1999). Recent trends in aquaculture. Agarwal Printers, 1174, P. Sharma Road, Meerut. 550-556.
- AOAC. (1990). Official Methods of Analysis. 15th Edition, Association of Official Analytical Chemist, Washington DC.
- APHA. (2012). Standard methods for examination of water and waste water (22nd ed.), American Public Health Association, Washington.
- Bergheim, A., Gausen, M., Naess, A., Holland, P.M., Krogedal, P. & Crampton, V. (2006). A newly developed oxygen injection system for cage farms. *Aquacultural Engineering* 34(1): 40–46. <https://doi.org/10.1016/j.aquaeng.2005.04.003>.
- Boyd, C.E. (1982). Water quality management for pond fish culture. Elsevier Scientific Publishing Company, Amsterdam, the Netherlands. 318 pp.
- Boyd, C.E. (1995). Potential for sodium nitrate to improve environmental conditions in aquaculture ponds. *World Aquaculture*, 26 (2): 38-39.
- Boyd, C.E. (1998). Pond water aeration systems. *Aquacultural Engineering* 18: 9-40.
- Boyd, C.E. & Pillai, V.K. (1984). Water quality management in aquaculture. Special publication No. 22. Central Marine Fisheries Research Institute, Cochin, India.
- CFPCC. (2019). Fisheries National Data Base. Central Fisheries Promotion and Conservation Center. Ministry of Agriculture and Livestock Development. Balaju, Kathmandu, Nepal.

- Collins, C. (1994). Tips of feed and feeding for catfish and baitfish. *Aquaculture Magazine* 20(4): 68-71.
- Das, P.C., Ayyappan, S., Jena, J.K., Singh, S.K., Patamajhi, P., & Muduli, H.K. (2004). Effect of aeration on production and water quality changes in intensive carp culture. *Indian Journal of Fisheries* 51(2): 173-183. <https://epubs.icar.org.in/index.php/IJF/article/view/7185>.
- Debnath, C., Sahoo, L., Datta, M., & Ngachan, S.V. (2014). Production potential of sophore barb (*Puntius sophore*) in polyculture- a field trial in Tripura. *Fishery Technology* 51: 78-81.
- DOFD. (2018). Annual Report. Directorate of Fisheries Development, Balaju. 54 pp.
- Duan, Y., Dong, X., Zhang, X. & Miao, Z. (2011). Effects of dissolved oxygen concentration and stocking density on the growth, energy budget and body composition of juvenile Japanese flounder, *Paralichthys olivaceus* (Temminck et Schlegel). *Aquaculture Research*, 42: 407–416. <https://doi.org/10.1111/j.1365-2109.2010.02635.x>.
- Hollerman, W.D. & Boyd, C.E. (1980). Nightly aeration to increase production of channel catfish. *Transactions of American Fisheries Society* 109(4): 446–452. DOI: [10.1577/1548-8659\(1980\)109<446:NATIPO>2.0.CO;2](https://doi.org/10.1577/1548-8659(1980)109<446:NATIPO>2.0.CO;2)
- Inglis, G.J., Hayden, B.J., Ross, A.H. (2000). An Overview of Factors Affecting the Carrying Capacity of Coastal Embayments for Mussel Culture. NIWA, Christchurch. Client Report CHC00/69: vi+ 31 p.
- Jena, J.K. (1998). Input management in carp culture for optimization of production levels. Ph.D. Thesis. Orissa University of Agriculture and Technology, Bhubaneswar.
- Knud-Hansen, C.F., & Pautong, A.K. (1993). On the role of urea in pond fertilization. *Aquaculture* 114 (3-4): 273-283. [https://doi.org/10.1016/0044-8486\(93\)90302-F](https://doi.org/10.1016/0044-8486(93)90302-F).
- Lai-fa, Z. & Boyd, C.E. (1988). Nightly aeration to increase the efficiency of channel catfish production. *The Progressive Fish-Culturist* 50(4): 237–242. [https://doi.org/10.1577/1548-8640\(1988\)050<0237:NATITE>2.3.CO;2](https://doi.org/10.1577/1548-8640(1988)050<0237:NATITE>2.3.CO;2).
- Loyacano, H.A. (1974). Effects of aeration in earthen ponds on water quality and production of white catfish; *Aquaculture* 3: 261-271. [https://doi.org/10.1016/0044-8486\(74\)90076-3](https://doi.org/10.1016/0044-8486(74)90076-3).
- Mayer, K., Sneed, E. & Eschmeyer, P.T. (1973). Second Report to fish farmers. Bureau of Sport Fisheries and Wildlife Resources Publication 113, Washington, USA.
- Parker, N.C. & Suttle, M.A. (1987). Design of airlift pumps for water circulation and aeration in aquaculture. *Aquacultural Engineering* 6(2): 97-110. [https://doi.org/10.1016/0144-8609\(87\)90008-2](https://doi.org/10.1016/0144-8609(87)90008-2).
- Pawar, N.A., Jena, J.K., Das, P.C., & Bhatnagar, D.D. (2009). Influence of duration of aeration on growth and survival of carp fingerlings during high density seed rearing. *Aquaculture* 290(3-4): 263-268. <https://doi.org/10.1016/j.aquaculture.2009.02.030>.
- Qayyum, A., Ayub, M., & Tabinda, A.B. (2005). Effect of aeration on water quality, fish growth and survival in aquaculture ponds. *Pakistan Journal of Zoology* 37(1), 75-80.
- Singh, S.B., Ghosh, S. R., Reddy, P.V. G.K., Dey, R.K. & Mishra, B.K. (1980). Effect of aeration on feed utilization by common carp fingerlings. *Journal of the Inland Fisheries Society of India* 12: 64- 69.
- Tiemeirer, O.W. & Deyoe, C.W. (1973). Producing Channel catfish, *Ictalurus punctatus* (Rafinesque) production in ponds. Doctoral Dissertation. Auburn University, Auburn, Alabama, USA.
- Tilak, K.S., Lakshmi, S.J. & Susan, T.A. (2002). The toxicity of ammonia, nitrite and nitrate to the fish *Catla catla* (Hamilton). *Journal of Environmental Biology* 23(2): 147-149.



ASSESSING THE VALUE CHAIN AND PROJECTING THE ECONOMIC FEASIBILITY OF COMMERCIAL PANGASIUS FISH FARMING IN NEPAL

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ABSTRACT

This research investigates the value chain analysis of Pangasius (*Pangasianodon hypophthalmus*) in 12 districts of Nepal, including Chitwan, Parsa, Nawalparasi, Rupandehi, Kapilbastu, Sunsari, Morang, Jhapa, Sarlahi, Dang, Kailali, and Surkhet, in 2024. A purposive sampling method was used to select 750 direct beneficiaries, primarily Pangasius farmers, from whom primary data were collected through semi-structured interviews utilizing a pre-tested questionnaire. Findings indicated that only a small number of these farmers have successfully marketed their products. Additionally, some farmers imported fry from India, raising them to fingerlings before selling to local farmers. Economic assessment using Benefit-Cost Ratio (B/C ratio), Net Present Value (NPV), and Internal Rate of Return (IRR) demonstrated that commercial Pangasius farming is financially viable under the assumptions used in the 20-year projection model. The analysis showed a positive NPV, an IRR above the assumed discount rate, and a B/C ratio greater than 1, indicating that projected benefits exceed projected costs. However, there is a notable absence of Pangasius processing in the area. The value chain is primarily controlled by retailers and given that Pangasius farming is relatively new in Nepal, most marketed fish are sourced from India. The research highlights significant potential for Pangasius aquaculture in Nepal, driven by an abundance of freshwater resources and suitable climatic conditions.

Keywords: Pangasius, economic, feasibility, net present value, internal rate of return, value chain

INTRODUCTION

Nepal, located in the central part of South Asia, enjoys unique geographical conditions. Snow-capped mountains border the country's territory in the North. Due to this, Nepal has the third-largest freshwater reserve on the planet (Action Contre La Faim 2024). Nepal's freshwater derived from glaciers, snowmelt, and rainfall accounts for an estimated 2.27% of the world supply (WB and ADB 2021). According to the Asian Disaster Preparedness Center (2021), the current estimate of the average total surface water annually available in the country is 225 billion m³ per annum, equivalent to an average flow of 7,125 m³/s or about 7,422 m³/person/year. The major river systems of Nepal are Mahakali, Karnali, Narayani (Gandaki), and Koshi with tributaries mixing into these major river streams emanating from the Himalayas.

Nepal, a landlocked country, possesses approximately 745,000 hectares of freshwater habitats, covering about 5% of its total area and comprising rivers, lakes, ponds, wetlands, reservoirs, and irrigated rice fields (Sharma 2008). The abundance of water bodies in Nepal gives it the right environmental conditions for the rearing of different indigenous and exotic fish species. The practice of fishery and making economic livelihood out of it has been a long-established tradition in Nepalese agriculture. Although aquaculture is an emerging sector in Nepal that started in the early 1950s, the contribution of this domain to economic livelihood creation among Nepalese can't be neglected.

According to MOALD (2023), the total fisheries sector contribution to Nepalese GDP in the year 2023 was 1.5%.

Currently, pond aquaculture has evolved to become the most practical and well-liked aquaculture production technology in Nepal and occupies more than 90% of fish production in Nepal (Budhathoki and Sapkota 2018). As per MOALD (2023), there are 49,862 fishponds in Nepal stretched over an area of 22,380 ha. In 2021/22, the total fish production in Nepal reached an all-time high of an impressive 77,320 mt indicating increasing interest and productivity of the aquaculture sector in Nepal MOALD (2023).

The diversity in climatic zones ranging from temperate to sub-tropical regions in Nepal provides an ideal platform for the cultivation of both warm-water and cold-water fish species in Nepal. Initially, certain ethnic groups such as Tharu, Bhote, Darai, Majhi, Kumal, Gurung, etc. were traditionally involved in capture fisheries. However, as the livelihood opportunities from fish farming seemed profitable, people from all ethnic communities are equally engaged in commercial activities of fish production in Nepal. Aquaculture is extended to 55 districts of the nation and has generated employment for 584,839 individuals (Rijal and Jha 2020). According to Budhathoki and Sapkota (2018), activities like genetic improvement of carps, and successful induced breeding of three major carps, rohu (*Labeo rohita*), catla (*Catla catla*), and mrigal (*Cirrhinus mrigala*) helped in the development of fish farming in Nepal. Currently, Carps, Pangasius, Tilapia, Catfish, and Rainbow trout are the most prevalent species (Chaudhary 2007).

Pangas catfish, known as Pangasius (*Pangasianodon hypophthalmus*), belong to the family Pangasiidae under the order Siluriformes (Gupta 2016). Pangasius is widely distributed in India, Bangladesh, Pakistan, Myanmar, the Malaya peninsula, Indonesia, Vietnam, Java, and Thailand. In recent years, Pangasius have also been introduced to Nepal as an exotic fish species (Bhatta et al. 2024). In the local context, this fish species is also termed 'Panhus' or 'Baikhi'. Viet Nam is the main exporter and Pangasius is a relatively recent species in international trade, but it is now being exported to a growing number of countries summing to a staggering number of 130 (FAO 2016). This species is advantageous over Indigenous fish species (Lakra and Singh 2010); is hardy to culture, have a small culture cycle, high stock capacity, high disease resistance and high export demand in the international market, and is compatible with other species for polyculture (Ali et al. 2005; Ayyappan et al. 2006). Market demand for Pangasius in Nepal is high mainly due to delicacy, taste, lower market price, and the presence of fewer spines in the fish body. Pangasius is primarily reared in ponds and cages, at higher stocking density (around 60-80 fish/m²) grown for 6-8 months depending on the need of the market and harvested when the weight of the fish is around 1 kg (Waycott 2020). The cultivation of Pangasius in Nepal has seen significant growth, because of favorable climatic conditions, abundant freshwater resources, and conducive natural environment conditions.

Compared with the traditionally dominant carp-based aquaculture system in Nepal, Pangasius offers several complementary advantages for commercial aquaculture. While carps remain the backbone of pond aquaculture in Nepal due to established seed systems, farmer familiarity, and consumer acceptance, Pangasius has emerged as a promising species because of its shorter grow-out period, tolerance to higher stocking densities, consumer preference for fewer intramuscular bones, and suitability for intensive or semi-intensive production systems. Therefore, Pangasius should be considered not as a substitute for carp, but as a complementary species that can diversify farm income, improve market supply, and support commercial aquaculture expansion in suitable Terai and inner-Terai production pockets.

The evolving demand for this species and with extending interest of fish farmers have made it critical for the promotion and management of aquaculture ponds oriented in Pangasius farming. Therefore, the objective of this paper is to thoroughly evaluate the existing value chain and economic sustainability of Pangasius farming within the country by taking different selected fish production districts as a reference for the study. The paper focuses on the economic analysis dimension of Pangasius farming, examining the direct and indirect costs involved in fish rearing, potential revenue, profitability of potential investment, and projections of income and expenses of Pangasius farming for 20 years. The study will help market actors understand investment requirements, resource allocation, and potential returns from Pangasius farming. It will also support policymakers in assessing how Pangasius aquaculture can contribute to farmer income, national fish production, and improved dietary protein availability.

MATERIALS AND METHODS

Sampling and source of data

The research investigated the possibility of Pangasius (*Pangasianodon hypophthalmus*) farming across 12 selected districts in Nepal specifically Chitwan, Parsa, Nawalparasi, Rupandehi, Kapilbastu, Sunsari, Morang, Jhapa, Sarlahi, Dang, Kailali, and Surkhet during 2024 as highlighted in Figure 1. The selected districts are some of the highest fish-producing districts and regions where Pangasius farming is steadily increasing (Figure 2). The information on the total pond and total fish production in the sampled districts is mentioned in Figure 2. To conduct the study a purposive (judgment) sampling method was employed to ensure the selection of the respondents who are directly engaged in Pangasius farming for baseline data collection. Purposive sampling was preferred to gain better value chain and cost-related insights from the farmers regarding Pangasius fish. Around 750 fish farmers were selected for the projection study, mainly considering their engagement in the production, management, and marketing of Pangasius.

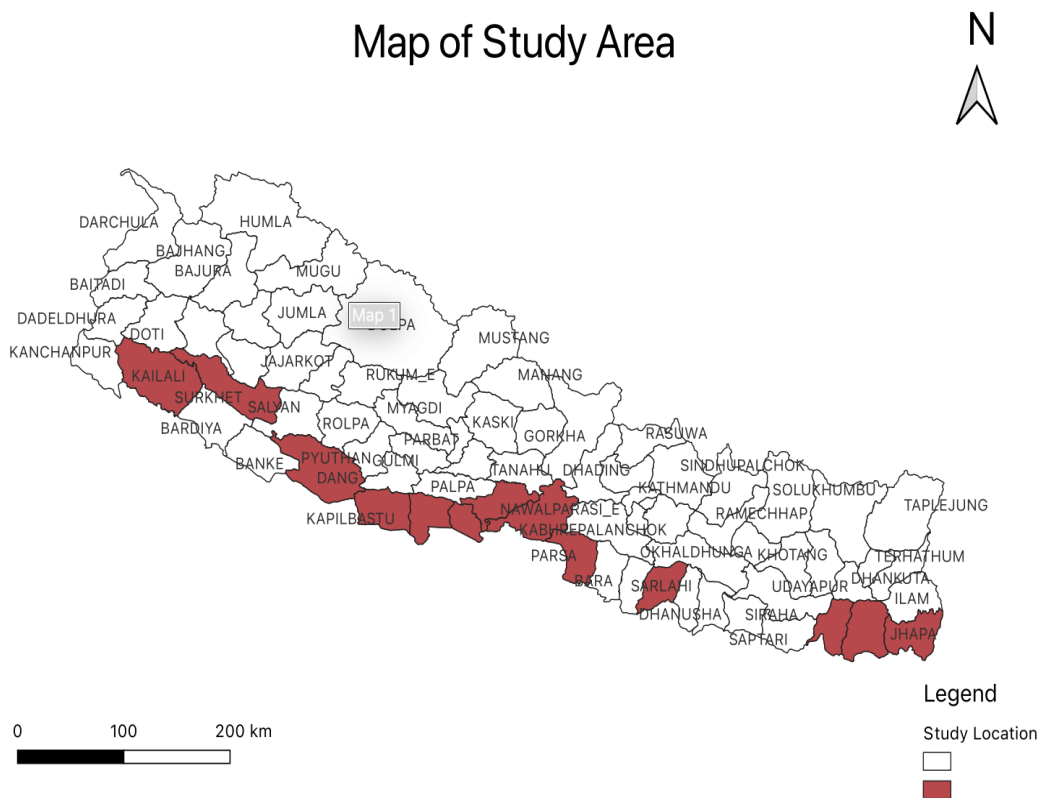


Figure 1: Map showing the study area

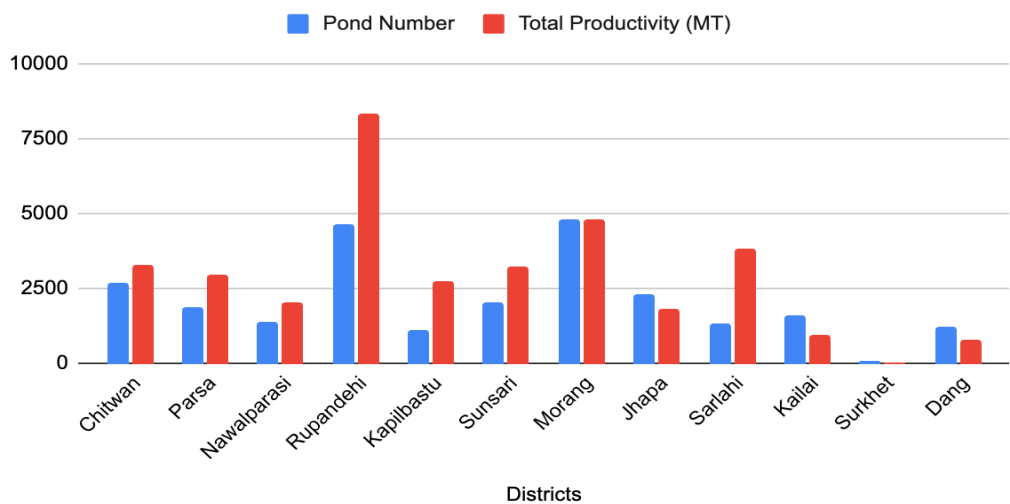


Figure 2: Number of fish ponds and total fish production across the selected sample districts

Primary data for the research were collected through semi-structured interviews, which allowed to gather of a combination of structured and open-ended responses from the participants in the survey. These interviews were preceded by a testing of pre-tested questionnaires for their reliability and validity. The questions covered essential aspects of the value chain, production practices, input sourcing, costs incurred, sales channel, and revenue generated. This approach ensured the reliable collection of data related to the general value chain of Pangasius farm and provided enough quantitative baseline to conduct a detailed 20 years of projections of income and expenses baselining the information received from the farmers as the assumptions. Additionally, secondary data were obtained from government databases, official reports, and previous studies on the economic assessment of Pangasius farming in South Asia to support the detailed economic projections.

Methods and techniques of data organization and analysis

The information obtained from the baseline survey among the respondents was used to design the assumptions for completing the detailed projections and economic feasibility of Pangasius farming in Nepal. The information collected from the survey was coded, tabulated, and analyzed using MS Excel 2023.

Key assumptions

In this study, several key assumptions were used to model and project the economic feasibility of Pangasius farming in Nepal. The model assumes that each farm utilizes an average land area of 4.5 hectares, with 3 hectares allocated specifically for pond construction, supporting an estimated 12 ponds per farm. The total planned area for this model covers 750 hectares, with a total of 250 farms included in the analysis, benefiting 750 direct participants. Some of the other model assumptions are presented in Table 1.

Table 1: Key assumptions used in the economic modeling of Pangasius farm

Particulars	Unit	Rate
Land utilization area per farm	Hectare	4.50
Total pond area per farm	Hectare	3.00
Total pond per farm	Number	12.00
Total planned area for model	Hectare	750.00
Number of beneficiaries	Number	750.00
Land rent per farm (Yearly recurring cost)	NRs	900,000.00
Electricity cost per year per farm (3000 per month-yearly recurring cost)	NRs	36,000.00
Medicine and lab consumables per farm (Yearly recurring cost)	NRs	50,000.00
Discount rate	Percentage	8%
Total farms	Number	250.00

RESULTS

Economic analysis

Infrastructure investment

Infrastructure investment refers to key investment that is required for upgrading and developing critical facilities for aquaculture operations. In the case of fish farming, the construction of ponds, water supply systems, feed storage systems, etc. falls into this category. These kinds of costs are required to be needed upfront for fish farming to ensure efficient, sustainable, and profitable operations from the outset.

In the present study, the infrastructure investment was divided into the construction of ponds, a water supply system, fencing, electrification, and equipment and tools as shown in the Table 2. Construction of ponds is the largest investment at NRs 3,000,000, followed by the water supply system at NRs 3,500,000. Other significant costs include feed storage (NRs 1,500,000), fencing (NRs 2,000,000), and electrification (NRs 300,000). Equipment and necessary tools like nets and crates come at a combined cost of NRs 1,320,000, which includes items such as scoop nets, weighing scales, and transport equipment.

Table 2: Infrastructure investment breakdown used in the present study

Item	Price NRs
Ponds construction	3,000,000.00
Water supply system	3,500,000.00
Feed storage cost	1,500,000.00
Fencing costs	2,000,000.00
Electrification cost	300,000.00
Equipment cost	1,000,000.00
Scoop net, Drag net, and Cast net	300,000.00
Crates and transport equipment costs	20,000.00
Cost of weighing scale	70,000.00
Office and operation room costs	500,000.00
Furniture costs	50,000.00
Grand total	12,240,000

Non-labor recurrent costs

Nonlabor recurrent costs are recurring expenses in fish farming operations that are useful to ensure smooth operation but do not involve labor costs. Expenses for water, electricity, feed, and any kind of medicines for the fish farm can be kept in this category of costs incurred in fish farming. Proper understanding and management of these identified non-labor recurrent costs are significant as they are directly associated with the sustainability and profitability of fish farming-related operations. The recurring operational costs for Pangasius farming in this study covered several essential inputs and services required for the operation of the farm. Land lease costs of NRs 900,000 and feed costs calculated NRs 2,846,250 were some of the highest fields on which most of the amount was directed as indicated in Table 3.

Table 3: Recurrent operational costs breakdown

Item	Unit Price	Total Price NRs
Land lease cost	900,000.00	900,000.00
Fingerling cost	4.00	110,000.00
Feed cost	57.50	2,846,250.00
Electricity	36,000.00	36,000.00
Medicine and Lab consumables	50,000.00	50,000.00
Fingerling transportation (input)	1.00	27,500.00
Liming	45.00	67,500.00
Fertilizer (organic and inorganic)	12,000.00	144,000.00

Labor recurrent costs

In contrast to non-labor recurrent costs, labor recurrent costs can be classified as expenses that incur due to employees' engagement in fish farming-related operations. Wages, benefits, and any

additional costs related to employee management, such as training and insurance come under these cost-related headings in a fish-related enterprise. Both the skilled and non-skilled manpower used in the production of fish, harvesting, and marketing of the fish can be included in this section. Effective management of these costs is essential for the overall profitability of the fish farm while also ensuring the laborers are motivated and competent in meeting the demands of the operation. Under the labor recurrent fixed costs in this study, two cost headings were considered. The harvesting cost is set at NRs 1,600 per farm, totaling NRs 192,000 for the required amount of harvested fish. Similarly, the permanent salary accounted for a total of NRs 468,000 per farm with 12 ponds stretched in 3 ha of water surface area (Table 4).

Table 4: Recurrent labor expenses breakdown

Items	Unit Price	Total Price NRs
Harvesting Cost	1,600.00	192,000.00
Permanent Staff Salary	19,500.00	468,000.00

Operating revenue

The total revenue from the Pangasius farm is determined by the multiplication of the yield of fish per farm size which is 4.5 ha on average and the market price of the fish. The projections derived for each farm suggest a yield of 127,500 kgs of fish per farm. With a market price of NRs 250/kg, the total revenue across all 250 farms is calculated to be NRs 32,512,500. However, since a lot of time will be dedicated to the fishpond, farm construction, and equipment installment, the commercial business is only expected to generate revenue from the second year of operation. The substantial revenue forecasted from the study highlights the possible financial benefits of pursuing Pangasius farming in the selected region. The detailed structure of revenue for the first year is shown in the Table 5.

Table 5: Operating revenue from the Pangasius farm

Items	Unit Rate	First-year	Second year
Yield per farm			127,500.00
Total revenue	250.00	-	32,512,500.00
Net profit/loss per hectare		- 34,962,500.00	9,355,000.00

Economic indicators

Discounted cash flows

The expected inflows and outflows of money over 20 years were projected to assess the financial viability of an investment in Pangasius farm. Over the 20 years of forecasted value, the financial viability of the Pangasius farm seems promising after the first year. In Year 1, there is an initial loss of NRs 34,962,500 per hectare, primarily due to high upfront costs for infrastructure and setup (Table 5). But from the second year onwards, the Pangasius farms are expected to generate consistent profits with the value of net profits ranging between NRs 7.5 million to 9.5 million (Figure 3).

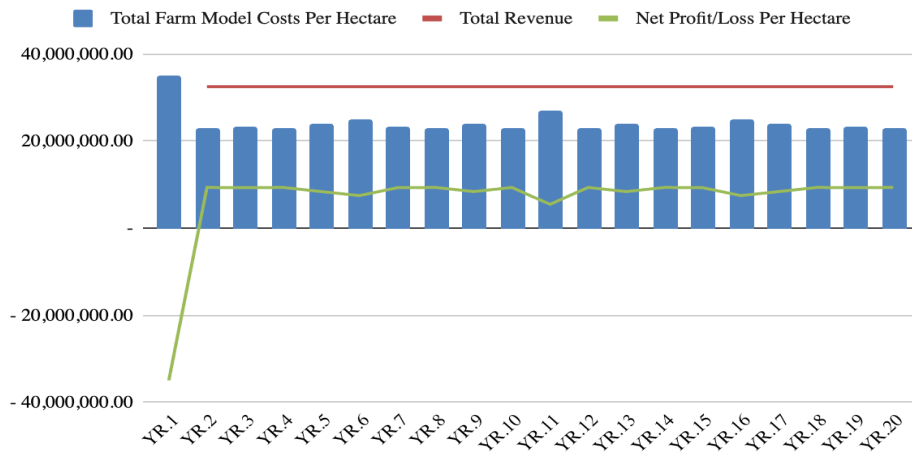


Figure 3: Cash flow forecasting for 250 Pangasius farms for a time duration of 20 years

Net present value

The Net Present Value was calculated using the standard discounted cash flow formula for uneven annual cash flows:

$$NPV = \sum [CF_t / (1 + r)^t] - C_0$$

Where CF_t is the net cash flow in year t , r is the discount rate, t is the year of occurrence, and C_0 is the initial investment cost. Since annual net cash flows vary across the 20-year projection period, each year's net cash flow was discounted separately rather than applying an annuity approximation.

Two discount rates, 8% and 10%, were applied to test the sensitivity of the investment returns under alternative capital cost assumptions. Using a 10% discount rate, the NPV is calculated to be NRs 34,997,537.87, which reflects the present value of the future cash flows generated by Pangasius farming. Similarly, the value of NPV calculated by using an 8% discount rate was NRs 45,605,944.82 (Figure 4).

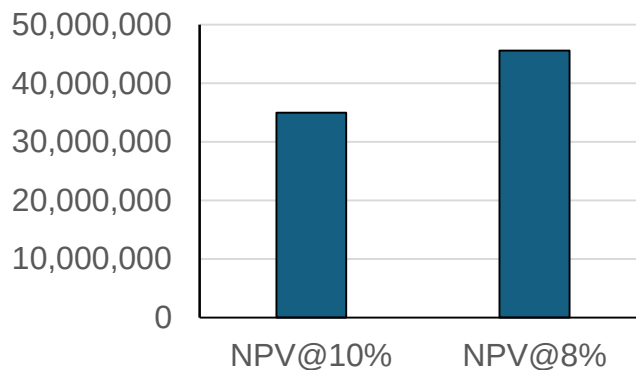


Figure 4: NPV calculated on the cash flow with discounted factors of 10% and 8%, respectively

Internal rate of return

The IRR represents the discount rate at which the Net Present Value (NPV) of future cash flows equals zero. In other words, it's the rate at which the project breaks even in terms of its costs and returns. The Internal rate of return (IRR) in this study was determined to be 25.11%, indicating a strong return on investment for Pangasius fish farming. The high IRR suggested that Pangasius fish farming could not only be profitable but also provide better financial results to the ones invested in this business, making it a highly desirable and lucrative aquaculture sector for investment.

Benefit-cost ratio

The benefit-cost ratio (B/C ratio) was estimated to assess the relative financial efficiency of Pangasius farming. The B/C ratio was calculated as the ratio of total benefits to total costs. For the first full production year, total revenue was estimated at NRs 32,512,500 while net profit was estimated at NRs 9,355,000. Based on these figures, the implied total production cost was NRs 23,157,500. The resulting B/C ratio was therefore estimated at 1.40, indicating that every NRs 1.00 invested in production generated approximately NRs 1.40 in gross benefit. Since the B/C ratio is greater than 1, the result supports the financial feasibility of Pangasius farming and is consistent with the positive NPV and IRR findings.

Value chain analysis of Pangasius

Value chain actors are an integral part of the value chain of Pangasius farming and are actively involved in different stages of the product like production, processing, distribution, management, and marketing of the finished products. As the fish chain moves from raw material to the finished product, each actor within the chain plays a crucial role in adding value to the products (Kolavalli et al. 2015). The value chain begins with the input suppliers such as fingerlings providers, feed manufacturers, suppliers of medicines, chemicals, finance, and other tools and equipment required for operationalizing the farms. These inputs are essential for the producer, the fish farmer, who manages the ponds, raises the Pangasius and ensures their growth through labor and farm management. Once the fish attain marketable size after 6-8 months of culture, the role of processors becomes essential. As the processing of Pangasius is not well developed in Nepal, most of the minor processing of the fish is done either by the farmers themselves or by the lead collectors of fish products within the region. The role of traders such as wholesalers and collectors is equally important to those who handle the cold chain logistics of the fish products. As observed from the field study, the traders are also involved in bulk selling of fish to retailers and other business-to-business bulk buyers such as Hotels, and Party Palaces, where they get a good profit margin per unit weight of the fish compared with selling more conventional retail channels.

At the retail level, retailers such as local markets, and restaurants provide the product to the final consumers, whose preferences and demands influence the entire value chain. Consumers buy these products from retailers with a small quantity of fish purchased. Along the value chain, there are enabling actors within the value chain like the Fisheries Development Center (FDC), Banking and Financial Institutions (BFIs), Nepal Agricultural Research Council (NARC), Agricultural Knowledge Center (AKC) that offers support in financial, technical, and marketing of adherence to the production of Pangasius fish as per national fisheries standards. A general representation of the value chain of Pangasius as synthesized from the field study is presented in Figure 5.

This study identified key constraints in Pangasius value chain which are detailed in Table 6.

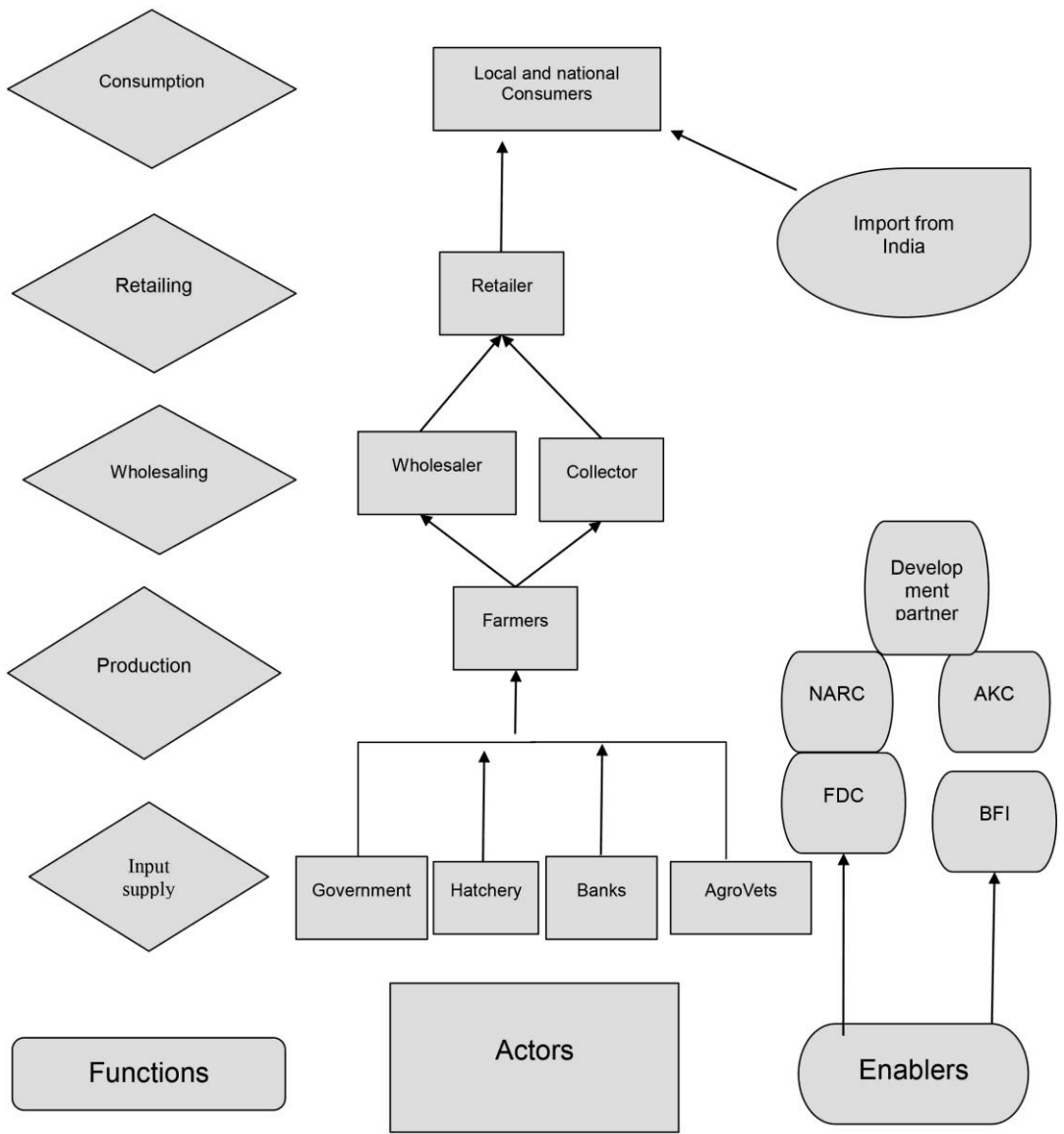


Figure 5: Summary of existing value chain analysis of Pangasius farming in Nepal

Table 6: Identified value chain constraints and potential solution

Constraint	Impact	Potential Solutions
Inadequate infrastructure (ponds)	Reduced production capacity, increased disease risk	Upgrade existing ponds, and construct new ponds with bio-security measures
Limited access to quality fish fingerlings	Lower survival rates, inconsistent growth	Establish local fingerling production facilities, improve quality control; and reduce reliance on Indian imported fry
Slow adoption of advanced production technology	Inefficient resource use, lower yields	Provide training and subsidies for farmers to adopt modern technologies
Lack of proper and climate-smart water management systems	Water scarcity, pollution, disease outbreaks	Install solar-powered water pumps, implement efficient irrigation systems
Inconsistent feed supply chain	Fluctuating feed costs, quality issues	Construct feed storage units, promote local feed production
Volatility in feed availability	Increased production costs, reduced profitability	Diversify feed sources, explore alternative feed ingredients
Disease outbreaks	High mortality rates, economic losses	Implement bio-security measures, improve disease surveillance
Climate change and environmental vulnerability	Decreased water availability, increased temperatures	Develop climate-resilient farming practices, promote sustainable aquaculture

DISCUSSION

The findings from the present value chain research indicated that only a small number of *Pangasius* farmers were able to market their fish effectively, which highlights a significant challenge in the commercialization of locally farmed *Pangasius*. On the contrary, the demand for *Pangasius* seems high but the number of producers is very low which also corresponds to the findings of Gurung et al. (2016), who conducted a value chain analysis of *Pangasius* fish in Rupandehi and Nawalparasi districts of Nepal. The limited success of the *Pangasius* is due to the underdeveloped fish value chain in Nepal, where farmers often confront difficulties in marketing their harvested fish. Some of the farmers have also been observed importing fry from India, raising the fingerlings and selling it to the local farmers. As *Pangasius* farming is still in the early stages of development in Nepal, the value chain analysis highlights a continued dependence on imported fish seed and finished products from neighboring countries, particularly from India, where the average production cost ranges from INR 65-70 (Rehman and Sharma, 2023). This reliance may constrain the development of a self-sustaining and competitive *Pangasius* aquaculture industry in Nepal by limiting domestic production capacity and increasing vulnerability to external market dynamics. As the *Pangasius* value chain continues to develop in Nepal, it is imperative to address the key constraints identified through both field

investigations and secondary data analysis. Some of the constraints, summarized in Table 6, represent critical challenges that must be overcome to enhance the efficiency, sustainability, and competitiveness of the Pangasius farming sector.

Similarly, Pangasius farming in Nepal demonstrates strong potential for future expansion despite being at an early stage of development. However, realizing the projected growth and economic potential will require coordinated support, strategic investment, and targeted interventions from government agencies, the private sector, research institutions, financial organizations, and other stakeholders across the value chain. The project's internal rate of return indicates significant profitability potential, while the net present value remains positive, reflecting favorable financial conditions. These findings are consistent with those of Khoi (2018), who demonstrated the financial feasibility of Pangasius farming for smallholder fish farmers in Vietnam using net present value (NPV) and internal rate of return (IRR) as key investment appraisal indicators. Additionally, the nationwide initiative of promotion of Pangasius farming is expected to create a notable number of employment opportunities, enhancing local livelihoods and community welfare.

The estimated B/C ratio of 1.40 further demonstrates the economic viability of Pangasius farming, indicating that the projected returns exceeded production costs during the first production cycle. This finding supports the commercial potential of Pangasius aquaculture in Nepal, provided that critical production and market-related factors, including the availability of quality feed and fingerlings, effective water management, and efficient market linkages, are adequately maintained.

CONCLUSION

The value chain and projected economic assessment revealed that Pangasius farming and its marketing are feasible in sampled 12 districts of Nepal. The demand for Pangasius is high; however, domestic production has not kept pace with the increasing market demand. Therefore, the findings of this study highlight the need for targeted interventions across the Pangasius value chain to improve production efficiency, strengthen market linkages, and enhance the sector's capacity to meet the growing consumer demand and market acceptance.

The study indicated that the value chain of Pangasius is largely controlled by retailers. Consumer preference for Pangasius is primarily driven by its low price, ease of preparation, desirable taste, and nutritional benefits. The study favored that regions in Nepal possess considerable potential for Pangasius farming owing to the abundance of freshwater resources and favorable temperature conditions for its culture.

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REFERENCES

- Action Contre La Faim. (2024). Nepal's water resources in the face of climate change. Retrieved from <https://www.actioncontrelafaim.org/en/headline/nepals-water-resources-in-the-face-of-climate-change/>.
- Ali, M.Z., Haque, M.K.I., Parveen, R., Hussain, M.G., & Mazid, M.A. (2005). Growth and reduction of cost of production of *Pangasius hypophthalmus* (Sauvage, 1878) with alternate feeding schedules. *Indian Journal of Fisheries*, 52(4): 397-404.
- Asian Disaster Preparedness Center. (2021). Water sector policies and guidelines of Nepal (ADPC/CARE/WAT/NP-03). Retrieved from <https://www.adpc.net/igo/category/ID1811/doc/2022-otj7NA-ADPC-Water Sector Policies and Guidelines of Nepal.pdf>.
- Ayyappan, S., Jena, J.K., Gopalakrishnan, A., & Pandey, A.K. (2006). Carp breeding and seed production. In S. Ayyappan, J. K. Jena, A. Gopalakrishnan, & A. K. Pandey (Eds.), *Handbook of Fisheries and Aquaculture* (1st ed., pp. 245-278). New Delhi, India: Directorate of Information and Publications of Agriculture, Indian Council of Agricultural Research (ICAR).
- Bhatta, D.D., Pant, K.R., Sapkota, L., & Upadhyay, G. (2024). A comprehensive SWOT analysis of *Pangasius* production in Kailali District, Nepal. *AMC Journal (Dhangadhi)*, 5(1): 57-64. <https://doi.org/10.3126/amcjd.v5i1.69122>.
- Budhathoki, R., & Sapkota, B. (2018). Fish farming in Nepal: Trend and consumption level. *Acta Scientific Agriculture*, 2(9): 109-115.
- Chaudhary, A. (2007). Estimation of small-scale fisheries production development trend in Nepal. *NCC Journal*, 5(1): 9-16. <https://doi.org/10.3126/nccj.v5i1.56>.
- FAO. (2016). The state of world fisheries and aquaculture 2016: Contributing to food security and nutrition for all. Food and Agriculture Organization of the United Nations.
- Gupta, S. (2016). *Pangasius pangasius* (Hamilton, 1822), a threatened fish of the Indian subcontinent. *Journal of Aquaculture Research & Development*, 7: 400-402. <https://doi.org/10.4172/2155-9546.1000400>.
- Gurung, S., Shrestha, S., Rajthala, S., & Karki, J. (2016). Value chain of *Pangasius* (*Pangasius hypophthalmus*) in Rupandehi and Nawalparasi districts of Nepal. *SSRG International Journal of Life Sciences*, 2(6): 712-728. <https://doi.org/10.21276/ijlssr.2016.2.6.11>.
- Khoi, L.N.D. (2018). Organic value chain analysis: The case of *Pangasius* in Vietnam. *International Journal of Science and Research*, 7(12): 239-243. <https://doi.org/10.21275/ART20193397>.
- Kolavalli, K., Mensah-Bonsu, A., & Zaman, S. (2015). Agricultural value chain development in practice: Private sector-led smallholder development (Discussion Paper No. 01460). International Food Policy Research Institute. Retrieved from <https://cgspace.cgiar.org/server/api/core/bitstreams/e79e852d-b2fc-4d50-b3c6-c989af04e0f8/content>.
- Lakra, W.S., & Singh, A.K. (2010). Risk analysis and sustainability of *Pangasianodon hypophthalmus* culture in India. *Genetics & Biodiversity*, 15(1): 34-37.
- MOALD. (2023). Statistical information on Nepalese agriculture. Ministry of Agriculture and Livestock Development. Retrieved from <https://moald.gov.np/wp-content/uploads/2023/08/Statistical-Information-on-Nepalese-Agriculture-2078-79-2021-22.pdf>.
- Rehman, A., & Sharma, B. (2023). A study of the growth potential and economic viability of *Pangasius* farming in the Varanasi area of Uttar Pradesh using different stocking densities. *The Pharma Innovation Journal*, 12(6): 535-539. Retrieved from <https://www.thepharmajournal.com/archives/2023/vol12issue6/PartG/12-5-707-993.pdf>.

- Rijal, P.K., & Jha, S.K. (2020). Status and development trend of aquaculture and fisheries in Nepal. *Nepalese Journal of Aquaculture and Fisheries*, 6-7: 1-12.
- Sharma, C.M. (2008). Freshwater fishes, fisheries, and habitat prospects of Nepal. *Aquatic Ecosystem Health & Management*, 11(3): 289-297. <https://doi.org/10.1080/14634980802317329>.
- Waycott, B. (2020). Pangasius farming: An overview. The Fish Site. Retrieved from <https://thefishsite.com/articles/pangasius-farming-an-overview>.
- WB & ADB. (2021). Climate risk country profile: Nepal. World Bank Group and Asian Development Bank.



GENDER ANALYSES IN AQUACULTURE AND FISHERIES EDUCATION, RESEARCH AND EXTENSION INSTITUTIONS IN NEPAL

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ABSTRACT

Present study assessed gender imbalance and ways out in aquaculture and fisheries education, research and extension institutions in Nepal. Primary data were collected using semi-structured questionnaires from fisheries students (n = 20), teaching faculty (n = 7) in the universities, research scientists and technical officers (n = 14) in the Nepal Agricultural Research Council and extension staffs (n = 41) in the local, provincial and federal government offices. Gender gap was relatively less in academia (24%) than research (60%) and extension institutions (65%). Inadequate government motivation, unequal opportunities in practice, gap in recruitment and double responsibilities were major reasons. Therefore, necessary gender inclusive policies and programs with women capacity enhancement were recommended.

Keywords: Aquaculture, Fisheries, Gender equality, Gender imbalance

INTRODUCTION

Aquaculture and fisheries are one of the important agriculture subsectors in Nepal providing livelihoods to 520,000 people and contributing 0.44% to national GDP and 1.83% to the Agricultural GDP (CFPCC 2023; Gautam and Sapkota 2023). Aquaculture is growing rapidly but still the country is not self-reliant on fisheries products and Nepal imports 3732 mt fish (Gautam and Sapkota 2023). Nepal's total fish production accounts 113,736 mt on 2022/23 with aquaculture contributing 92,736 mt. Per capita fish availability is 3.9 kg/year in Nepal while world's per capita fish consumption is 20.7 kg/year (FAO 2024). There is a need of improved aquaculture technologies, skilled manpower to transfer technologies to farmers and sustainable management of fisheries to increase fish production. Aquaculture is suitable to both men and women compared to fisheries. In this sector both women and men participate in different parts of the aquaculture value chain, including pond and cage management, feeding and harvesting, hatchery operations, processing and packaging, marketing and sales and business management and finance. Women are especially active in small-scale aquaculture and post-harvest activities in many countries, while increasing numbers are also involved in technical and leadership roles. With proper training, access to resources, and gender responsive policies, aquaculture can provide income, food security, and employment opportunities for everyone regardless of gender.

This sector provides opportunities for women to empower economically and make them financially self-dependent by farming and engaging in their value chain development. Despite having huge potential in aquaculture and fisheries women are under-represented. Both men and women have been playing significant role in aquaculture and fisheries development. However, women's status in education, research and extension remained unexplored yet. Across Asia—including Nepal, but excluding Japan, Malaysia, and Sri Lanka, regular sex-disaggregated statistics for aquaculture are

not collected, even though they would shed light on how many women are employed, the types of work they do, and how this is changing over time (Brugere and Williams 2017). However, in academia better data are available (Egna et al. 2012). The lack of comprehensive and timely data on women in aquaculture is one reason why women are invisible in aquaculture policy (Brugere and Williams 2017). Present study aims to examine the status of gender equality in aquaculture and fisheries with focus on three pillars; education, research and extension institutions having a crucial role on sustainable development of aquaculture and fisheries in the country. Understanding gender status and causes of gender inequality across these three interconnected areas of study would become possible to plan and develop inclusive policies and programs, and ensure that interventions are equitable and effective.

MATERIAL AND METHODS

The study was based on primary data collection from universities (Agriculture and Forestry University, Tribhuvan University), fisheries related research stations of the Nepal Agricultural Research Council (NARC) and the federal (Department of Livestock Services, Central Fisheries Promotion and Conservation Center under Ministry of Agriculture and Livestock Development), provincial (Directorate of Livestock and Fisheries under Ministry of Agriculture and Land Reform) and local offices from different municipalities. Respondents were selected randomly and interviewed using semi-structured questionnaires during July to August 2024. Among universities, Agriculture and Forestry University (AFU) and Tribhuvan University (TU) were selected because fisheries and aquaculture higher education degrees are provided in these universities. Respondents were fisheries students ($n = 20$) from AFU and TU, faculty members ($n = 7$) from AFU and TU, research staff ($n = 14$) from NARC and extension staff from government offices ($n = 41$). Sample size were 24%, 64% and 26% of total number of students, faculty members and extension staff, respectively while full census was conducted for NARC due to small number of staffs. Sample size varied with the respective total numbers of individuals in each category. It was lowest in government extension offices due to large number of staffs (158). Among students, male and female respondents were 50% each while among teaching faculty male and female respondents were 57% and 43%, respectively. Likewise, male and female respondents were 79% and 21%, respectively from NARC while it was 100% female from government extension offices. Secondary data were collected from official records and publications of respective institutions/organizations.

Gender gap was calculated by subtracting number of women respondents from the number of men respondents (Akbash et al. 2019). Data were analyzed for frequency and percentage by using descriptive statistics on Microsoft Excel. The analyzed data were presented in tables and charts.

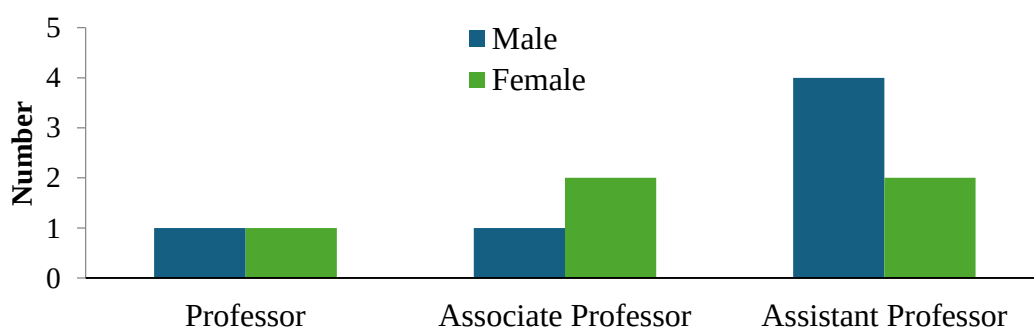
RESULTS AND DISCUSSION

Status of gender in surveyed institutions

Education: Male and female student enrollment and teaching faculty status in AFU and TU is given in Table 1. There were altogether 84 students in AFU and TU and among them 45 were from B.Sc. Fisheries, 14 were from M.Sc. Fisheries, 15 were from M.Sc. Aquaculture and M.Sc. Zoology (Fish Biology and Aquaculture) and 2 were from Ph.D. Aquaculture. There were 11 teaching faculty in aquaculture and fisheries and among them 6 were male and 5 were female. Rank wise 2 were professor including one female, 3 associate professor including 2 female and 6 assistant professors including 2 females (Figure 1).

Table 1: Number of student and teaching faculty in universities

Particular	Agriculture and Forestry University	Tribhuvan University	Total
Students			
Male	41	7	48 (57%)
Female	28	8	36 (43%)
Sub-total	69	15	84
Teaching faculty			
Male	2	4	6 (55%)
Female	3	2	5 (45%)
Sub-total	5	6	11
Total	74	21	95

**Figure 1:** Status of academic rank of faculty members in universities

Research: Status of male and female scientists and technical officers in the fisheries related research stations such as National Fishery Research Centre, Godawari, Fishery Research Stations at Trishuli and Pokhara, Rainbow Trout Fishery Research Station, Dhunche, Directorate of Agricultural Research at Tarahara, Parwanipur and Khajura is given in Table 2.

Table 2: Number of scientists and technical officers in NARC Research stations

Particular	Scientist	Technical officer	Total
Male	4	6	10 (71%)
Female	1	3	4 (29%)
Total	5	9	14

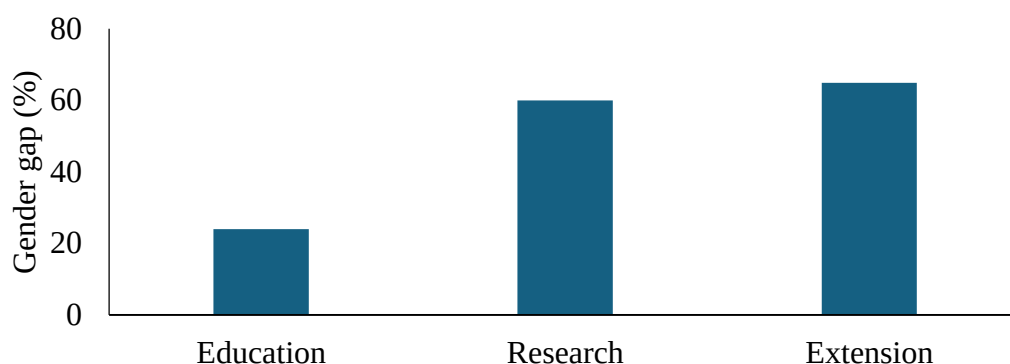
Extension: Number of Technical staffs involved in aquaculture and fisheries development and extension service delivery in the Central Fisheries Promotion and Conservation Center at the Federal level, Directorate of Livestock and Fisheries at the Provincial level and Agriculture Development Office/Section/Service Center at the local level is given in Table 3.

Table 3: Number of Technical staffs involved in the extension services including officers and non-officers

Technical staff	Federal	Provincial	Local	Total
Male	32	58	27	117 (74%)
Female	15	18	8	41(26%)
Total	47	76	35	158

Gender gap

Number of men and women involved in education, research and extension institutions found to be an unequal. Representation of women compared to men was very low in extension (26%) and research (29%) than in education (43% in students and 45% in teaching faculty). This has led to huge gender gap in three components. Gender gap in representation varied from 24% in education to 65% in extension. Similarly, the unequal representation of women in the leadership position was found in respective institutions. Lower gender gap was found in education (33%) followed by research (60%) and extension (73%). Gender gap in universities particularly among students (25%) should be decreased further because future workforce for three components will come from this pool. Enrollment trend in higher education in AFU has shown that girls students have been enrolled more in Fisheries academic programs compared to agriculture and veterinary science. Fisheries students after graduation are expected to fulfill technical manpower requirements of the nation. Low women representation in research and extension institution showed a need of urgent improvement in recruitment process to increase women's participation. Similar underrepresentation in agricultural research was reported in Nepal by Stads et al. (2015). In order to improve women's participation in aquaculture development, technical training, networking opportunities, and institutional support are needed for women (Neupane and Rai 2025).

**Figure 2:** Gender gap (%) in education, research and extension institutions

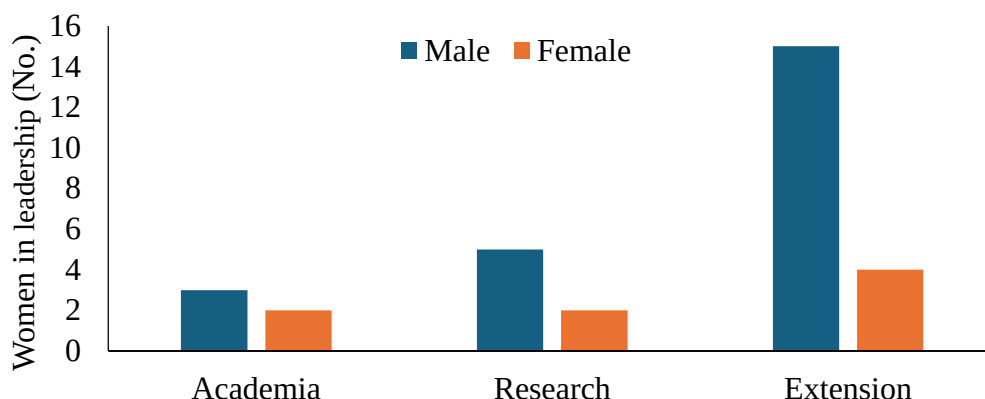


Figure 3: Women in leadership position in academia, research and extension institutions

Factors affecting gender imbalance

Based on the suggestions collected from online questionnaire survey following major reasons for under-representation of women were identified.

- Inadequate government motivation and support: such as low reservation for women in recruitment, promotion, trainings and committees.
- Unequal opportunities in practice: Although policy does not discriminate but still most of the female staff do not get the opportunities in capacity building activities such as training, seminar, workshop and others in practice.
- Lack of women fellowship for higher education: Less female graduates from universities to recruit in related public organizations, specifically under NARC and office under Ministries for government services.
- Public Service Commission does not recruit staff on time so that there is a huge gender gap.
- Work overload due to dual (office and chores) responsibility of women.
- No provision of special gender focused policy and program in respective institutions/offices.
- Women are receiving secondary priority in office responsibilities and unfair access to resources.
- Ignoring voice of women and underrating their work.
- Most of women do not feel comfort to stay away from family due to practical family problem and lack of self-confidence to work away from home.

Challenges for the women

Following challenges have been reported in fisheries and aquaculture education, research and extension institutions.

- Ignore the women voice
- Unfair share of the resources
- Underrating female's capacity and work
- Intense field work/physical work in water

- Dual responsibility with balancing office and family
- Concern of safety and security

Ways forward to overcome the challenges

Following ways were suggested by respondents to overcome above challenges.

- Equality in access, participation, representation, and benefit-sharing.
- Develop a system for patience to listen the voice of female and support them.
- Gender balance representation in decision making positions. Positive and women friendly working environment where they feel respect and value.
- Recognizing voice of the women
- Provide time to time gender related refresher training for all.
- Incorporate the women's role in curricula.
- Funding for female too for their capacity development as equal as the male.
- Safe and secured working place.
- Family support needed.

CONCLUSION

The findings of the study showed that gender inequality exists in aquaculture and fisheries. If current trend continues, then the further gap will increase and it will take decades to fulfill the gender gap. It will negatively affect the aquaculture and fisheries development in the country. For the gender equality women targeted policies and programs with developing the women friendly environment are needed to attract and participate more women to this sector.

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REFERENCES

- Akbash, K.S., Pasichnyk, N.O., & Rizhniak, R.Y. (2019). Generalization of calculation methods for gender indices in demographic and social statistics. *Regional Statistics*, 8(2): 170-183. <https://doi.org/10.15196/RS080205>.
- Brugere, C., & Williams, M. (2017). Profile: Women in Aquaculture. <https://genderaquafish.org/portfolio/women-in-aquaculture/>.
- CFPCC. (2023). Annual Progress Report. Central Fisheries Promotion and Conservation Center, Balaju, Kathmandu.
- Egna, E., Reifke, L., & Gitonga, N. (2012). Improving gender equity in aquaculture education and training: 30 years of experiences in the Pond Dynamics/Aquaculture, Aquaculture, and AquaFish Collaborative Research Support Program. *Asian Fisheries Science*, Special Issue 255: 119-128.
- FAO. (2024). The State of World Fisheries and Aquaculture 2024 – Blue Transformation in action. Rome. <https://doi.org/10.4060/cd0683en>.
- Gautam, S., & Sapkota, P. (2023). Status and development trend of aquaculture and fisheries in Nepal. *Nepalese Journal of Aquaculture and Fisheries*, 10: 1-13.

- Neupane, P., & Rai, S. (2025). Role of women in the mitigation of climate change impact on aquaculture in Chitwan, Nepal. *Fishery Technology*, 62(3): 389-394. <https://doi.org/10.56093/ft.v62i3.148107>.
- Stads, G.J., Shrestha, H.K., Manandhar, H.K., & Gao, L. (2015). Nepal: ASTI–NARC Country Factsheet. International Food Policy Research Institute (IFPRI) and Nepal Agricultural Research Council (NARC).

ASSESSMENT OF MUSTARD OIL CAKE AS SUPPLEMENTARY FEED FOR CARPS IN PONDS WITH AND WITHOUT PERIPHYTON ENHANCEMENT

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ABSTRACT

An experiment was conducted to assess potential of locally available mustard oil cake as supplementary feed for carps in farmers' pond at Phulloria and Majhui of Chitwan district for 210 days. The experiment included four treatments: T1 - 50% rice bran + 50% mustard oil cake, T2 - 25% rice bran + 75% mustard oil cake, T3 - 100% mustard oil cake and T4 - 50% mustard oil cake + bamboo substrate with three replications. Carps including rohu (*Labeo rohita*), mrigal (*Cirrhinus mrigala*), catla (*Labeo catla*), silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Hypophthalmichthys nobilis*), grass carp (*Ctenopharyngodon idella*) and common carp (*Cyprinus carpio*) were stocked at a density 15000 fish/ha in all treatments. Bamboo substrate covering 1% pond surface area was fixed in T4 ponds. Feeding rate was 3% body weight per day. Daily weight gain, survival and yields of Rohu was higher ($P<0.05$) in T4 than rest treatments. Growth of Mrigal and Silver carp was higher ($P<0.05$) in T2 than other treatments. The gross margin and benefit cost ratio were higher ($P<0.05$) in T4 than other treatments. Thus, based on higher gross margin and low AFCR feeding 50% MOC with periphyton enhancement is found to be appropriate for semi-intensive carp polyculture.

Keywords: Bamboo substrate, feed ingredients, growth, yield, AFCR

INTRODUCTION

The total aquaculture production of Nepal has increased from 28,000 mt. in 2006/07 to 83,623 mt. in 2023 (CFPCC, 2023) which is mainly contributed by carp polyculture (90%). The species combination of carp polyculture are indigenous major carp: rohu (*Labeo rohita*), mrigal (*Cirrhinus mrigala*), catla (*Labeo catla*) and exotic carp like silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Hypophthalmichthys nobilis*), grass carp (*Ctenopharyngodon idella*) and common carp (*Cyprinus carpio*). In carp polyculture fish production is affected by species combination, stocking density, pond fertilization, feed quality and quantity as well as ecological condition (Alam et al. 2002; Gooley and Gavine 2003; Rahman et al. 2017). Carps are herbivores and omnivores and they can be easily reared on natural food and supplementary feed that contain protein, carbohydrate, lipid, vitamin and mineral in sufficient amount. Different agriculture byproducts are used as supplementary feed that may include oil cakes, bran, beans etc (Cruz 1997; Rahman et al. 2006; Hernandez et al. 2014). The major ingredients used to make fish feed at farm are rice bran and mustard oil cake due to their easy availability where mustard oil cake (MOC) is used as protein source. Farmers are found to mix these ingredients at different proportions to make feed. Some of the farmers are also found to use only mustard oil cake as supplementary feed for carp in Nepal however, no scientific studies have been done on its use as feed and its effect on carp growth and production yet.

Feed alone constitutes higher than 60% of total production cost in carp polyculture (Laudari et al. 2017). Different inclusion level of feed ingredients and ingredient prices affect the cost of feed and overall production cost. Using local ingredients in fish feed indeed reduces the feed cost but needs to know what and how much to include so that fish growth and production can be increased without deteriorating water quality. Further, adding substrates to ponds for periphyton enhancement can reduce feed input as well as increases production of rohu, catla and common carp (Rai and Yi, 2012; Jha et al. 2018). Present study was carried out to assess the potential of mustard oil cake as supplementary feed for carps in ponds with and without periphyton enhancement.

MATERIALS AND METHODS

The present study was conducted in 12 farmers' pond in Phulloria and Majhui in Chitwan district for 210 days starting from 29th April to 26th November 2021. The average pond size was 142.7 m² ranging from 70 m² to 190 m². The experiment was conducted in completely randomized design (CRD) with four treatments and three replications as shown in Table 1. Since majority of farmers were small scale, they use rice bran and mustard oil cake at equal ratio (1:1) as supplementary feed in Nepal. It was considered as control with variation in their proportion in other treatments. In treatment T4, the feed quantity was reduced to half due to the provision of bamboo substrate which have been already proven to reduce feed quantity in other different studies (Jha et al. 2018).

Table 1: Description of treatments

Treatments	Fish species	Feed
T1 (Control)	Carp	50% rice bran and 50% mustard oil cake
T2	Carp	25% rice bran and 75% mustard oil cake
T3	Carp	100% mustard oil cake
T4	Carp	50% mustard oil cake and bamboo substrate

All experimental ponds were drained and dried, then applied agricultural lime (CaCO₃) at a rate of 500 kg/ha for disinfection. After 15 days of liming, ponds were filled with water and dry cow dung dissolved in water was applied at the rate of 15000 kg/ha. Urea and DAP was applied three days later at the rate of 470 g/100 m² and 350 g/100 m² (Knud-Hansen and Pautong 1993).

Substrates for the periphyton growth was prepared using bamboo slats in the form of mat. Each bamboo slat was 1 m long and 3-5 cm wide. The number of bamboo slats to be kept in each pond was calculated as per requirement. The slats were tied into rectangular bamboo mat by using strings keeping space in between slats. The bamboo mats covered 1% of total pond surface area. Bamboo substrate was suspended vertically in the water column with the top two edges tied to plastic bottles as floats and bottom edges tied to stones as sinkers in pond.

Carp fingerlings were obtained from Darai Fish Hatchery in Sundi, Chitwan. Stocking of fingerling was done after the 7 days of installation of substrate. Prior to stocking fingerlings were acclimatized for 10-15 minutes inside the plastic bag filled with oxygen and water floated on the surface of the pond. The stocking density for all treatments was 15,000 fish/ha. Average size of stocked fish were silver carp (21.3±0.01 g/fish), bighead carp (13.5±0.01 g/fish), grass carp (0.6±0.01 g/fish), rohu (7.0±0.01 g/fish), mrigal (9.5±0.01 g/fish) and common carp (1.0±0.02 g/fish) in all treatments. The stocking combination and density of each species is given in Table 2.

Table 2: Stocking densities of carps in different treatments (fish/ha)

Species	Composition (%)	Stocking density (fish/ha)
Rohu	20	3000
Mrigal	10	1500
Silver carp	20	3000
Bighead carp	10	1500
Grass carp	20	3000
Common carp	20	3000
Total	100	15000

Fish were fed with freshly prepared dough of mustard oil cake and rice bran at 1:1 ratio in T1 and 3:1 in T2 while 100% mustard oil cake was fed in T3 and T4. Fish were fed at 3% body weight per day in first three treatments during culture period, however, feed in T4 was reduced to half thus making it only 1.5% of total fish biomass in pond. They were fed once a day at around 10 a.m. Feed was given in a feeding tray in each pond. Feed rations were adjusted monthly based on sampled weight of fish species. The stocked fish were sampled monthly by using drag net. From the total stocked fish, only 10% fish of each species was sampled and weighed using a top-pan balance.

Harvesting was done first with partial draining followed by repeated netting and then complete draining and hand picking. Final individual and total weight of each species was taken in the weighing balance in gram. Fish were counted and their individual weight was recorded to determine survival, growth, and yields while extra fish such as small indigenous species (SIS) and Ghungi were weighed in bulk and their total weight was also taken.

The crude protein analysis of feed ingredients and supplementary feed was done according to AOAC (1990) at Animal Nutrition Laboratory, AFU, Rampur, Chitwan. For the crude protein analysis, Kjeldahl method was followed.

Water quality parameters such as transparency (using Secchi disk), temperature (using DO meter), dissolved oxygen (using DO meter) and pH (using pH meter) were recorded in situ between 7 to 9 a.m. fortnightly while total alkalinity, ammonia, SRP and chlorophyll-a were analysed monthly following APHA (2012) at laboratory of Fisheries Program.

Financial return was calculated by using gross margin analysis. Gross margin was calculated by deducting total variable costs from total income (Upton, 1964). Variable costs were calculated based on the market price while gross return was calculated based on the product sold at farm gate price.

The experimental data was analysed using one-way analysis of variance (ANOVA) followed by Duncan's Multiple Range Test (DMRT). All statistical analyses were performed using SPSS (V 21). Differences were considered significant at an alpha of 0.05 ($p < 0.05$). All means were given with $\pm$ standard error (S.E.).

RESULTS

Proximate analysis of feed ingredients and supplementary feed

The proximate analysis of experimental feed ingredients and feed was done for crude protein content and results are shown in Table 3.

Table 3: Proximate analysis of feed ingredients and supplementary feed

S.N.	Feed ingredient/feed	Composition	CP
1	Mustard oil cake (MOC)		30.1±0.2
2	Rice bran (RB)		12.0±0.2
3	Control (T1)	50:50 (RB:MOC)	21.0±0.1
4	T2	25:75 (RB:MOC)	25.4±0.2
5	T3	0:100 (RB:MOC)	30.1±0.2
6	T4	0:50 (RB:MOC)	30.1±0.2

Growth and yield of carps

Growth and yield of different carp were assessed based on the stocking and harvesting data. The growth and production of different carp is shown in Table 4.

Table 4: Growth performance of carp in different treatments during the experiment (mean±SE)

Parameters	T ₁	T ₂	T ₃	T ₄
Rohu				
Average stocking weight (g/fish)	7.03±0.01 ^a	7.03±0.01 ^a	7.02±0.00 ^a	7.02±0.01 ^a
Total stocking weight (g/100 m ²)	212.4±1.2 ^a	210.9±0.3 ^a	211.8±1.3 ^a	212.7±1.2 ^a
Average harvesting weight (g/fish)	218.4±2.7 ^d	238.6±1.8 ^c	258.4±3 ^b	286.8±3.2 ^a
Total harvesting weight (kg/100 m ²)	5.9±0.3 ^b	5.1±0.4 ^b	5.4±1.0 ^b	8.2±0.3 ^a
Daily weight gain (g/fish/day)	1.01±0.01 ^d	1.10±0.01 ^c	1.20±0.01 ^b	1.33±0.02 ^a
Total weight gain (kg/100 m ²)	5.7±0.3 ^b	4.9±0.4 ^b	5.2±1 ^b	8.0±0.3 ^a
Survival rate (%)	88.8±3.0 ^{ab}	71.9±6.4 ^{ab}	68.7±11.5 ^b	94.5±2.5 ^a
GFY (t/ha/yr)	1.02±0.05 ^b	0.89±0.07 ^b	0.93±0.17 ^b	1.43±0.04 ^a
NFY (t/ha/yr)	0.98±0.05 ^b	0.86±0.07 ^b	0.90±0.17 ^b	1.39±0.04 ^a
Mrigal				
Parameters	T ₁	T ₂	T ₃	T ₄
Average stocking weight (g/fish)	9.61±0.02 ^a	9.59±0.01 ^a	9.60±0.02 ^a	9.61±0.02 ^a
Total stocking weight (g/100 m ²)	145.3±0.6 ^a	144.7±1.0 ^a	145.7±0.8 ^a	146.7±1.9 ^a
Average harvesting weight (g/fish)	254.8±3.4 ^b	284.5±2.3 ^{ab}	293.3±10.3 ^a	266.3±14.7 ^{ab}
Total harvesting weight (kg/100 m ²)	3.0±0.1 ^a	2.8±0.1 ^a	3.0±0.3 ^a	3.1±0.2 ^a
Daily weight gain (g/fish/day)	1.17±0.02 ^b	1.31±0.01 ^{ab}	1.35±0.05 ^a	1.22±0.07 ^{ab}
Total weight gain (kg/100 m ²)	2.8±0.1 ^a	2.6±0.1 ^a	2.8±0.3 ^a	3.0±0.2 ^a
Survival rate (%)	76.6±2.6 ^{ab}	64.9±1.2 ^b	66.7±4.3 ^{ab}	77.8±5 ^a
GFY (t/ha/yr)	0.51±0.02 ^a	0.48±0.01 ^a	0.52±0.05 ^a	0.55±0.03 ^a
NFY (t/ha/yr)	0.49±0.02 ^a	0.46±0.01 ^a	0.49±0.05 ^a	0.52±0.03 ^a
Silver carp				
Parameters	T ₁	T ₂	T ₃	T ₄
Average stocking weight (g/fish)	21.32±0.01 ^a	21.32±0.02 ^a	21.30±0.02 ^a	21.32±0.01 ^a
Total stocking weight (g/100 m ²)	644.3±3.5 ^a	639.7±0.6 ^a	642.9±3.7 ^a	645.6±3.4 ^a
Average harvesting weight (g/fish)	357.2±21.3 ^{bc}	446.1±21.3 ^a	352.3±24.7 ^c	425.7±17.1 ^{ab}
Total harvesting weight (kg/100 m ²)	9.8±0.4 ^a	8.8±0.8 ^a	7.1±2.0 ^a	10.5±0.3 ^a
Daily weight gain (g/fish/day)	1.60±0.1 ^b	2.02±0.1 ^a	1.58±0.12 ^b	1.93±0.08 ^a
Total weight gain (kg/100 m ²)	9.1±0.4 ^a	8.2±0.8 ^a	6.4±2 ^a	9.9±0.3 ^a
Survival rate (%)	90.7±1.6 ^a	66±5.7 ^a	69.6±22.3 ^a	81.8±2.7 ^a
GFY (t/ha/yr)	1.70±0.07 ^a	1.53±0.13 ^a	1.23±0.35 ^a	1.83±0.04 ^a
NFY (t/ha/yr)	1.59±0.07 ^a	1.42±0.13 ^a	1.12±0.35 ^a	1.72±0.04 ^a
Bighead carp				

Parameters	T ₁	T ₂	T ₃	T ₄
Parameters	T ₁	T ₂	T ₃	T ₄
Average stocking weight (g/fish)	13.48±0.01 ^a	13.49±0.02 ^a	13.51±0.01 ^a	13.52±0.02 ^a
Total stocking weight (g/100 m ²)	203.8±1.3 ^a	203.6±1.0 ^a	205.0±1.3 ^a	206.5±2.6 ^a
Average harvesting weight (g/fish)	298.1±5.2 ^a	291.4±0.9 ^a	298±3.5 ^a	293.7±10.3 ^a
Total harvesting weight (kg/100 m ²)	2.9±0.0 ^a	3.4±0.3 ^a	3.2±0.2 ^a	3.5±0.3 ^a
Daily weight gain (g/fish/day)	1.36±0.02 ^a	1.32±0.00 ^a	1.35±0.02 ^a	1.33±0.05 ^a
Total weight gain (kg/100 m ²)	2.7±0.0 ^a	3.2±0.3 ^a	3.0±0.2 ^a	3.3±0.3 ^a
Survival rate (%)	64.5±1.2 ^a	77.1±6.7 ^a	71.3±5.0 ^a	78.3±4.1 ^a
GFY (t/ha/yr)	0.5±0.01 ^a	0.59±0.06 ^a	0.56±0.03 ^a	0.61±0.06 ^a
NFY (t/ha/yr)	0.47±0.01 ^a	0.55±0.06 ^a	0.52±0.04 ^a	0.58±0.06 ^a
Grass carp				
Parameters	T ₁	T ₂	T ₃	T ₄
Average stocking weight (g/fish)	0.63±0.01 ^a	0.62±0.01 ^a	0.61±0.01 ^a	0.63±0.00 ^a
Total stocking weight (g/100 m ²)	19.1±0.2 ^a	18.7±0.2 ^a	18.5±0.2 ^a	19.0±0.2 ^a
Average harvesting weight (g/fish)	422.9±4.7 ^a	455.2±16.9 ^a	381.3±71.8 ^a	464.3±5.0 ^a
Total harvesting weight (kg/100 m ²)	9.6±0.1 ^a	10.5±0.2 ^a	8.7±1.7 ^a	10.8±1.0 ^a
Daily weight gain (g/fish/day)	2.01±0.02 ^a	2.16±0.08 ^a	1.81±0.34 ^a	2.21±0.02 ^a
Total weight gain (kg/100 m ²)	9.6±0.1 ^a	10.5±0.2 ^a	8.6±1.7 ^a	10.8±1.0 ^a
Survival rate (%)	75.5±1.7 ^a	77.1±1.2 ^a	74.9±2.0 ^a	76.8±7.6 ^a
GFY (t/ha/yr)	1.68±0.02 ^a	1.83±0.04 ^a	1.51±0.3 ^a	1.87±0.17 ^a
NFY (t/ha/yr)	1.67±0.02 ^a	1.83±0.04 ^a	1.50±0.3 ^a	1.87±0.17 ^a
Common carp				
Parameters	T ₁	T ₂	T ₃	T ₄
Average stocking weight (g/fish)	1.01±0.02 ^a	1.02±0.01 ^a	1.01±0.01 ^a	1.03±0.00 ^a
Total stocking weight (g/100 m ²)	30.6±0.6 ^a	30.7±0.2 ^a	30.5±0.2 ^a	31.3±0.1 ^a
Average harvesting weight (g/fish)	428.6±7.8 ^a	549.1±20.7 ^a	519.9±130.0 ^a	547±13.7 ^a
Total harvesting weight (kg/100 m ²)	8.9±0.3 ^a	12.5±0.1 ^a	11.7±3.2 ^a	12.6±0.8 ^a
Daily weight gain (g/fish/day)	2.04±0.04 ^a	2.61±0.1 ^a	2.47±0.62 ^a	2.6±0.07 ^a
Total weight gain (kg/100 m ²)	8.9±0.3 ^a	12.5±0.1 ^a	11.7±3.2 ^a	12.6±0.8 ^a
Survival rate (%)	68.9±1.4 ^a	76.2±2.3 ^a	73.1±3.3 ^a	76.0±3.9 ^a
GFY (t/ha/yr)	1.55±0.05 ^a	2.18±0.02 ^a	2.04±0.56 ^a	2.19±0.14 ^a
NFY (t/ha/yr)	1.55±0.05 ^a	2.17±0.02 ^a	2.03±0.56 ^a	2.18±0.14 ^a

Mean value with same superscript letter in the same row are not significantly different (p>0.05)

Survival rate (%) of rohu in T4 was significantly higher (p<0.05) than in T3 and both of which were statistically at par (p>0.05) with T1 and T2. The average harvesting weight and daily weight gain of rohu in T4 was significantly highest (p<0.05) followed by T3, T2 and T1. However, the total harvesting weight, total weight gain, GFY and NFY of T4 was significantly higher (p<0.05) than rest of the treatments. The average harvesting weight and daily weight gain of mrigal in T3 was significantly higher (p<0.05) than T1 but both were at par (p>0.05) with T2 and T4. The survival rate of Mrigal in T4 was significantly higher (p<0.05) than in T2 while both were at par with T1 and T3. The average weight of silver carp at harvest in T2 was significantly higher (p<0.05) than in T1 and T3 but at par (p>0.05) with T4. The daily weight gain of silver carp in T2 and T4 was significantly higher (P<0.05) than T1 and T3 but at par (p>0.05) with each other. Similarly, the daily weight gain of silver carp in T1 and T3 were also at par (p>0.05) with each other.

Combined yield of carp

The overall survival, GFY and NFY of all carp did not differ significantly ($p>0.05$) among treatments (Table 6) except apparent food conversion ratio which was significantly ($p<0.05$) lower in T4 than all other treatments.

Table 6: Combined fish production in different treatments

Parameters	T ₁	T ₂	T ₃	T ₄
Average stocking weight (g/fish)	8.8±0.0 ^a	8.8±0.0 ^a	8.8±0.0 ^a	8.6±0.0 ^a
Total stocking weight (g/100 m ²)	1255.5±7.0 ^a	1248.2±1.5 ^a	1254.6±5.9 ^a	1261.8±8.9 ^a
Average harvesting weight (g/fish)	330.0±2.1 ^a	377.5±6.5 ^a	350.5±30.5 ^a	380.6±5.1 ^a
Total harvesting weight (kg/100 m ²)	40.1±0.1 ^a	43.2±0.9 ^a	39.1±7.3 ^a	48.8±0.3 ^a
Total weight gain (kg/100 m ²)	38.8±0.1 ^a	41.9±0.9 ^a	37.8±7.3 ^a	47.5±0.3 ^a
Overall Survival (%)	78.9±0.7 ^a	72.4±1.2 ^a	71.1±6.4 ^a	81.4±1.0 ^a
Overall GFY (t/ha/yr)	7.0±0.0 ^a	7.5±0.2 ^a	6.8±1.3 ^a	8.5±0.0 ^a
Overall NFY (t/ha/yr)	6.7±0.0 ^a	7.3±0.2 ^a	6.6±1.3 ^a	8.3±0.0 ^a
AFCR	4.0±0.3 ^b	3.7±0.4 ^b	4.1±0.9 ^b	1.5±0.1 ^a

Mean value with same superscript letter in the same row are not significantly different ($p>0.05$)

Water quality parameters

Among the water quality parameters, transparency and soluble reactive phosphorus showed significant difference among treatments (Table 7). Transparency was higher ($p<0.05$) in T1 than other treatments while the soluble reactive phosphorus was significantly higher ($p<0.05$) in T2 and T3 than T1 and T4.

Table 7: Summary of water quality parameters during experimental period (mean±SE)

Parameters	Treatment			
	T ₁	T ₂	T ₃	T ₄
Temperature (°C)	27.4±0.1 ^a (16.9-34.3)	27.6±0.1 ^a (18.1-33.2)	27.4±0.1 ^a (17.9-34.4)	27.5±0.3 ^a (18.0-33.4)
Transparency (cm)	32.7±2.8 ^a (12-59)	28±2.5 ^b (16-55)	28.2±0.2 ^b (17-43)	25.3±2.1 ^b (13-48)
pH	7.3 (6.3-9.2)	7.3 (6.6-8.9)	7.3 (6.5-9.4)	7.2 (6.5-9.2)
Dissolved Oxygen (mg/L)	3.6±0.2 ^a (1.3-7.7)	4±0.3 ^a (1.3-8.8)	4.2±0.4 ^a (1.4-8.0)	4.3±0.1 ^a (1.0-9.2)
Total alkalinity (mg/L as CaCO ₃)	152.1±40.9 ^a (46.0-302.4)	155.1±29.4 ^a (56.4-315.4)	150.7±20.2 ^a (57.5-322.0)	164.2±22.3 ^a (44.4-287.0)
Soluble Reactive Phosphorus (mg/L)	0.17±0.04 ^b (0.00-0.89)	0.39±0.17 ^a (0.00-1.20)	0.36±0.21 ^a (0.00-1.44)	0.22±0.03 ^b (0.00-0.87)
Total Ammonium Nitrogen (mg/L)	1.30±0.08 ^a (0.01-3.02)	1.12±0.10 ^a (0.08-2.44)	1.11±0.20 ^a (0.05-2.39)	1.06±0.12 ^a (0.05-2.31)
Chlorophyll-a (µg/L)	191.5±57.1 ^a (10.7-696.2)	189.2±21.7 ^a (11.9-452.2)	208.1±39.1 ^a (8.3-831.8)	246.5±52.9 ^a (36.9-709.2)

Mean value with same superscript letter in the same row are not significantly different ($p>0.05$)

Gross margin analysis

Gross margin analysis of present study has shown that the cost of feed (mustard oil cake) in T3 was significantly highest ($p<0.05$) than rest treatments while it was same in T1 and T4 ($p>0.05$) (Table 8). Similarly, rice bran was used in T1 and T2 where the cost of rice bran in T1 was significantly higher ($p<0.05$) than that in T2. In T3 the cost of MOC was significantly higher ($p<0.05$) than other treatments because 100% MOC was used in T3 as supplementary feed. However, there was no significant difference in all other variable costs among different treatments. The total variable cost in T4 was significantly lower ($p<0.05$) compared to all other treatments due to use of 50% MOC and periphyton enhancement in T4. The production cost of fish (NRs.92.2 $\pm$ 5.4 /kg) in T4 was significantly lower ($p<0.05$) than rest treatments with no significant difference ($p>0.05$) among treatments T1, T2 and T3. Similarly, the gross margin and B:C ratio of T4 was significantly higher ($p<0.05$) than rest treatments with no significant difference ($p>0.05$) among T1, T2 and T3 treatments.

Table 8: Gross margin analysis (NRs./100 m²) of different treatments during experimental period

Parameters	T1	T2	T3	T4
Variables (NRs./100 m ²)				
Seed	600.0 $\pm$ 0.0	600.0 $\pm$ 0.0	600.0 $\pm$ 0.0	600.0 $\pm$ 0.0
Lime	90.0 $\pm$ 0.0	90.0 $\pm$ 0.0	90.0 $\pm$ 0.0	90.0 $\pm$ 0.0
Urea	47.3 $\pm$ 0.0	47.3 $\pm$ 0.0	47.3 $\pm$ 0.0	47.3 $\pm$ 0.0
DAP	48.6 $\pm$ 0.0	48.6 $\pm$ 0.0	48.6 $\pm$ 0.0	48.6 $\pm$ 0.0
MOC	3526.0 $\pm$ 0.0 ^c	5219.4 $\pm$ 447.7 ^b	6406.8 $\pm$ 267.9 ^a	3304.7 $\pm$ 228.9 ^c
Rice bran	2742.7 $\pm$ 0.0 ^a	1353.2 $\pm$ 116.1 ^b		
Feeding tray	100.0 $\pm$ 0.0	100.0 $\pm$ 0.0	100.0 $\pm$ 0.0	100.0 $\pm$ 0.0
Substrate				297.3 $\pm$ 20.7
Total variable cost	7154.9 $\pm$ 508.8 ^a	7458.4 $\pm$ 563.7 ^a	7292.6 $\pm$ 267.9 ^a	4487.9 $\pm$ 248.7 ^b
Income (NRs./100 m ²)	12825.1 $\pm$ 27.0 ^a	13816.9 $\pm$ 281.5 ^a	12497.5 $\pm$ 2326.7 ^a	15610.9 $\pm$ 91.1 ^a
Production cost (NRs./kg)	178.6 $\pm$ 12.4 ^a	173.4 $\pm$ 16.9 ^a	203.0 $\pm$ 43.8 ^a	92.2 $\pm$ 5.4 ^b
Gross margin (NRs./100 m ²)	5670.2 $\pm$ 481.9 ^b	6358.5 $\pm$ 841.6 ^b	5204.9 $\pm$ 43.8 ^b	11123.0 $\pm$ 313.6 ^a
B:C ratio	1.8 $\pm$ 0.1 ^b	1.9 $\pm$ 0.2 ^b	1.7 $\pm$ 0.3 ^b	3.5 $\pm$ 0.2 ^a

Mean value with same superscript letter in the same row are not significantly different ($p>0.05$)

DISCUSSION

Growth and yield of carp

The present study of carp polyculture was carried out with four treatments to identify best supplementary feed for carps based on water quality, total fish production, and financial return.

The daily weight gain of different carps did not differ among treatments except rohu, mrigal and silver carp. rohu had significantly higher ($P<0.05$) growth and yield in T4 than in other treatments, indicating it benefited from both periphyton and supplementary feed containing high level of protein ((30.1 $\pm$ 0.1%) for better growth. Rohu has fringed inferior lips to browse and nibble periphyton grown on bamboo slats (Rai and Yi 2012). The results indicated that supplemental feed and periphyton are beneficial for the growth of rohu, as evidenced by the higher yield and growth of the fish in treatment T4. Moreover, MOC probably worked as effective fertilizer to enhance phytoplankton abundance that colonized over the bamboo mat which was not present in T3 relating to its non-significant difference ($p>0.05$) than T1 and T2. In an experiment, Mredul et al. (2022) using cattle manure and mustard oil cake as the organic fertilizers, showed that amount of nitrogen (5.44%) and Phosphorous (1.84%) in MOC was significantly higher than chicken manure. Similarly,

higher number of plankton, predominantly zooplanktons were found in ponds fertilized with MOC. Similarly, the weight of Rohu reached to 286.8 g in T4 which was followed by T3, T2 and T1 and can be comparable to other studies of same period and same location in Nepal (Jha et al. 2018). The proximate analysis of feed ingredients during present study showed that MOC contained $30.1 \pm 0.2\%$ CP and rice bran contained $12.0 \pm 0.2\%$ CP. It was reported that proximate composition of periphyton from different substrates varied from 9 to 32% protein (Thompson et al. 2002). Azim et al. (2001) estimated 27.19% crude protein in periphyton developed on bamboo, 14.63% on hizol branches, 18.74% on kanchi (bamboo shoot) and 12.69% on jute sticks. Therefore, higher protein level in MOC and periphyton enhanced rohu growth and yield in T4.

The growth performance of mrigal was significantly higher ($p < 0.05$) in 100% MOC feed (T3) than other treatments. This may occur because mrigal are bottom-feeders; the MOC settles at the bottom, generating detritus that the fish then consume. Mredul et al. (2022) reported that mustard oil cake contains more nutrient and also increases the pond productivity from which mrigal benefited. Silver carp in T3 exhibited a significantly lower average harvesting weight compared to all other treatments ($p < 0.05$). Conversely, T2 and T4 yielded significantly higher weights ($p < 0.05$), likely driven by low water transparency from abundant phytoplankton. As specialized phytoplankton feeders, the silver carp capitalized on this food source, mirroring the findings of Zhao et al. (2013), who reported enhanced silver carp growth in high-biomass plankton communities. In contrast, no significant differences ($p > 0.05$) were observed in the growth or yield of bighead, grass, and common carps. This indicates that these species did not utilize the available periphyton or the mustard oil cake supplementary feed.

In the present study, all cultured fish species exhibited satisfactory growth performance. However, the gross fish yields for mrigal and bighead carp were lower than those of the other species across all treatments. Additionally, the cumulative yield for all species across all treatments remained lower than the yields documented by Mazid et al. (1997). Despite this, the gross fish yield in treatment T4 reached 8.5 ± 0.0 t/ha/yr, which significantly exceeds the national average productivity of 5.57 t/ha/yr and the Chitwan district average of 5.2 t/ha/yr (MoALD, 2021). Furthermore, both the net and gross fish yields in this study surpassed the values reported by Poudel et al. (2020) and Mandal et al. (2022), which were 5.36 ± 0.05 t/ha/yr and 6.1 ± 0.6 t/ha/yr, respectively.

The variations in growth and yield can be attributed to the quality of the supplementary feed and the introduction of a bamboo substrate. Variation in Mustard Oil Cake (MOC) quality may have influenced fish growth. For instance, Capper et al. (1982) observed that incorporating up to 20% black MOC into common carp diets resulted in reduced body weight and a poor Feed Conversion Ratio (FCR). Conversely, the high crude protein (CP) content of the MOC used in this study (30% CP) directly benefited the fish, offering superior nutritional value compared to a standard 1:1 rice bran and MOC mixed feed.

Additionally, the periphyton-supporting bamboo substrate played a critical role. In treatments featuring the bamboo substrate, the FCR was notably low (1.5 ± 0.1). This finding aligns with Jha et al. (2018), who reported that carp polyculture integrated with small indigenous species (SIS), a 50% feed reduction, and a bamboo substrate achieved a significantly lower FCR (1.02) and higher total carp yield compared to conventional treatments utilizing 100% feed alone or 100% feed with SIS.

Water quality

During the study, the average water temperature and pH remained within the optimal range for carp polyculture (Boyd, 1998). Conversely, dissolved oxygen (DO) concentrations across all treatments

ranged from 3.6 ± 0.2 to 4.3 ± 0.1 mg/L, which is slightly below the recommended 5.0 to 7.0 mg/L threshold required for ideal carp growth (Alikunhi, 1957). These sub-optimal DO levels were likely caused by a combination of high seasonal temperatures, low water transparency, and elevated organic matter.

Water transparency was significantly higher in T1 than in the other treatments, indicating lower plankton density. As the inclusion level of mustard oil cake (MOC) increased across the treatments, transparency decreased. This trend suggests that MOC acted as an organic fertilizer, stimulating phytoplankton proliferation (Sarker et al., 2015; Jahan et al., 2013). This elevated phytoplankton biomass across all groups was further corroborated by high chlorophyll-a concentrations, which were driven by the combined nutrient inputs from commercial fertilizers and MOC.

Average total ammonia levels were also high, driven by intensive pond fertilization and the subsequent decomposition of accumulated MOC at the legacy pond bottom, a process known to generate ammonium gas (Mondal et al., 2014). Furthermore, soluble reactive phosphorus (SRP) levels were significantly higher in T2 and T3 ($p < 0.05$) compared to the other treatments. This increase directly corresponds to the higher levels of MOC in the feed; MOC contains approximately 1.84% phosphorus (Mredul et al., 2022), which is notably higher than the 0.63% found in rice bran (Cervantes-Pahm and Stein, 2010).

Gross margin

Gross margins were estimated using local market prices for inputs and outputs. Feed was the highest expense, followed by seed cost. Treatment 2 (T2) had the highest total variable cost due to the 75% mustard oil cake (MOC) inclusion.

Treatment 4 (T4) achieved the highest gross margin (NRs. $11,116.3 \pm 310.0/100 \text{ m}^2$) and total income (NRs. $15,610.9 \pm 91.1/100 \text{ m}^2$) ($p < 0.05$). This resulted from a combination of the highest fish yield and a lower variable cost (NRs. $4,494.6 \pm 245.2/100 \text{ m}^2$). The lower variable cost was driven by a reduction in total feed cost (NRs. $3,304.7 \pm 228.9/100 \text{ m}^2$), as feed was cut by half in T4.

Consequently, T4 produced a significantly higher benefit-cost (B:C) ratio (3.5 ± 0.2) than all other treatments ($p < 0.05$). This superior gross margin aligns with Poudel et al. (2020), who reported that enhancing natural food production in ponds elevates B:C ratios. Overall, the periphyton enhancement system reduced total feed costs by 50% and total variable costs by 40%.

CONCLUSION

From the results of present study, it can be concluded that mustard oil cake serves as a good source of nutrition for carp species and no significant difference in the growth and production of carps was found with different proportions of mustard oil cake in fish feed. Additionally, MOC was also not found to deteriorate the water quality with increasing level. Similarly, the use of substrates for the periphyton growth can significantly reduce the overall food cost along with significant increase in the growth and production of Rohu. The use of substrate with reduced feed was also found to significantly decrease the total variable cost and thereby increase the gross margin and B:C ratio. Hence use of 50% mustard oil with bamboo substrate was found to be appropriate in Nepal for small scale carp farmers.

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REFERENCES

- Alam, M.J., Kohinoor, A.H.M., Islam, M.S., & Mazid, M.A. (2002). Polyculture of carps using over-wintered fingerlings using different stocking densities. *Bangladesh Journal of Fisheries Research* 6(2): 117-124.
- Alikunhi, K.H. (1957). Fish culture in India. *Farm Bulletin* 20: 3-5.
- AOAC. (1990). *Official Methods of Analysis* (15th ed.). Association of Official Analytical Chemists, Arlington, VA.
- APHA. (2012). *Standard Methods for the Examination of Water and Wastewater* (22nd ed.). American Public Health Association, American Water Works Association, Water Environment Federation. <https://www.standardmethods.org/>.
- Azim, M.E., Wahab, M.A., Van Dam, A.A., Beveridge, M.C.M., Huisman, E.A. & Verdegem, M.C.J. (2001). Optimization of stocking ratios of two Indian major carps, rohu (*Labeo rohita* Ham.) and catla (*Catla catla* Ham.) in a periphyton-based aquaculture system. *Aquaculture*, 203(1-2): 33-49. [https://doi.org/10.1016/S0044-8486\(01\)00602-0](https://doi.org/10.1016/S0044-8486(01)00602-0).
- Boyd, C.E. (1998). *Water quality for fish pond aquaculture research and development series*. No.43. Auburn University, Alabama USA.
- Capper, B.S., Wood, J.F., & Jackson, A.J. (1982). The Feeding value for carp of two species of Mustard seed cakes from Nepal. *Aquaculture*, 29: 373-377. [https://doi.org/10.1016/0044-8486\(82\)90149-1](https://doi.org/10.1016/0044-8486(82)90149-1).
- Cervantes-Pahm, S.K., & Stein, H.H. (2010). Ileal digestibility of amino acids in conventional, fermented, and enzyme-treated soybean meal and in soy protein isolate, fish meal, and casein fed to weanling pigs. *Journal of Animal Science*, 88(8): 2674–2683. <https://doi.org/10.2527/jas.2009-2677>.
- CFPCC. (2023). *Annual Progress Report*. Central Fisheries Promotion and Conservation Center, Balaju, Kathmandu. <http://cfpcc.gov.np/index.php>.
- Cruz, P.S. (1997). *Aquaculture feed and fertilizer resource atlas of the Philippines*. FAO fisheries technical paper 366. <http://www.fao.org/docrep/003/W6928E/w6928e00.htm>
- Gooley, G., & Gavine F. (2003). *Integrated Agri- Aquaculture systems. A resource handbook for Austrralian industry development*. RIRDC publication no. 03/012.Rur.Res. Development Corporation, Canberra.
- Hernandez, M., Leyva, E.G., Gressler, P., & Krise, D. (2014). Effects of farm and commercial inputs on carp polyculture performance: participatory trial in an experimental field station. *Latin American Journal of Aquatic Research*, 42(3): 468-476. <https://doi.org/103856/vol42-issue3-fulltext-7>.
- Jahan, D.A., Hussain, L., Islam, M.A., & Khan, M. (2013). Comparative study of mustard oil cake and soyabean meal based artificial diet for Rohu (*Labeo rohita*). *The Agriculturists*, 11(1): 61-66. <http://dx.doi.org/10.3329/agric.v11i1.15244>.
- Jha, S., Rai, S., Shrestha, M.K., Diana, J.S., & Mandal, R.B. (2018). Production of periphyton to enhance yield in polyculture ponds with carps and small indigenous species. *Aquaculture Reports*, 9: 74-81. <https://doi.org/10.1016/j.aqrep.2018.01.001>.

- Knud-Hansen, C.F., & Pauotong, A.K. (1993). On the role of urea in pond fertilization. *Aquaculture*, 114 (3-4): 273-283. [https://doi.org/10.1016/0044-8486\(93\)90302-F](https://doi.org/10.1016/0044-8486(93)90302-F).
- Laudari, S., Yadav, C.N.R., Singh, A.K., & Mishra, R.N. (2017). Assessment of optimum feeding rate on growth and production of carp polyculture in Nepal. *Nepalese Journal of Aquaculture and Fisheries*, 3 & 4:26-33.
- Mandal, R.B., Rai, S., Shrestha, M.K., Jha, D.K., & Pandit, N.P. (2022). Effectiveness of Different measures to control Red Bloom in carp ponds. *Journal of Agriculture and Forestry University*, 5: 139-147. <https://doi.org/10.3126/jafu.v5i1.48457>.
- Mazid, M.A., Zaher, M., Begum, N.N., Ali, M.Z., & Nahar, F. (1997). Formulation of cost-effective feeds from locally available ingredients for carp polyculture system for increased production. *Aquaculture*, 151(1-4):71-78. [https://doi.org/10.1016/S0044-8486\(96\)01504-9](https://doi.org/10.1016/S0044-8486(96)01504-9).
- Mondal, S., Das, R., & Das, A.M. (2014). A comparative study on the decomposition of edible and non-edible oil cakes in the Gangetic alluvial soil of West Bengal. *Environmental Monitoring and Assessment*, 186: 5199-5207. <https://doi.org/10.1007/s10661-014-3769-7>.
- Mredul, M., Akkas, M.H., Elsaidy, A.E., Ali, N., Mondal, M.A.H., & Aslam, M.R. (2022). Using of mustard oil cake in safe organic aquaculture through increasing pond primary productivity. *Aquaculture Reports*, 23: 101073. <https://doi.org/10.1016/j.aqrep.2022.101073>.
- Poudel, R., Rai, S., Jha, D.K., & Mandal, R.B. (2020). Effect of Bamboo substrate on growth and production of carp and small indigenous fish. *Our Nature*, 18 (1): 38-48. <https://doi.org/10.3126/on.v18i1.34240>.
- Rahman, M.M., Verdegem, M.C.J., Nagelkerke, L.A.J., Wahab, M.A., Milstein, A., & Verreth, J.A.J. (2006). Growth, production and food preference of Rohu *Labeo rohita* (H.) in monoculture and in polyculture with common carp *Cyprinus carpio* (L.) under fed and non –fed ponds. *Aquaculture*, 257: 359-372. <https://doi.org/10.1016/j.aquaculture.2006.03.020>.
- Rahman, M.M., Das, S., Samad, M.A., Tanu, I.A. & Mofasshalin, M.S. (2017). Growth, production and economics of carp polyculture in fertilizer and feed-based ponds. *International Journal of Natural and Social Sciences*, 4(3): 1-9.
- Rai, S. & Yi, Y. (2012). Nibbling frequency of carps in periphyton- based aquaculture systems with and without supplemental feed. *Israeli Journal of Aquaculture-Bamidgeh*, 64: 818-822. <https://doi.org/10.46989/001c.20606>.
- Sarker, A.K., Saha, D., Begum, H., Zaman, A., & Rahman, M.M. (2015). Comparison of cake compositions, pepsin digestibility and amino acids concentration of proteins isolated from black mustard and yellow mustard cakes. *AMB Express*, 5(1): 1-6. <https://doi.org/10.1186/s13568-015-0110-y>.
- Thompson, F.L., Abreu, P.C., & Wasielesky, W. (2002). Importance of biofilm for water quality and nourishment in intensive shrimp culture. *Aquaculture* 203(3-4): 263-278. [https://doi.org/10.1016/S0044-8486\(01\)00642-1](https://doi.org/10.1016/S0044-8486(01)00642-1).
- Upton, M. (1964). A development of gross margin analysis. *Journal of Agricultural Economics*, 16(1): 111–117. <https://doi.org/10.1111/j.1477-9552.1964.tb00484.x>.
- Zhao, S.Y., Sun, Y.P., Lin, Q.Q., & Han, B. (2013). Effects of Silver carp (*Hypophthalmichthys molitrix*) and nutrients on the plankton community of a deep, tropical reservoir: An enclosure experiment. *Freshwater Biology*, 58(1): 100-113. <https://doi.org/10.1111/fwb.12042>.



GROWTH AND PRODUCTION PERFORMANCE OF OLD STOCK AND PURE LINE COMMON CARP (*Cyprinus carpio*) FRY AND FINGERLING UNDER DIFFERENT STOCKING DENSITIES

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ABSTRACT

A 150-day experiment from 4 May to 1 October 2021 evaluated the growth and production performance of old stock versus pure line common carp (*Cyprinus carpio*) fry at the Fisheries Development Centre in Geta, Kailali. Using a 2x3 factorial design, the study tested two treatments (old stock vs. pure line) across three stocking densities (20, 30, and 40 fry/m²). The fries were reared in 1 m³ hapas installed within a 300 m² earthen pond and fed a 32% crude protein commercial pellet diet at 5% body weight, split into two daily feedings (10 AM and 3 PM). Water temperature, dissolved oxygen, and pH were monitored on a weekly basis. The results demonstrated that pure line Common carp stocked at 40 fry/m² achieved significantly higher ($p < 0.05$) total harvested weight, total weight gain, extrapolated gross fish yield (EGFY), and extrapolated net fish yield (ENFY) compared to the old stock. Furthermore, this specific treatment combination yielded a significantly higher ($p < 0.05$) gross return and gross margin. Consequently, utilizing pure line Common carp at a stocking density of 40 fry/m² proved to be the superior management strategy for optimizing growth and production performance.

Keywords: Pure line Common carp, stocking density, survival rate, growth performance, yield

INTRODUCTION

Common carp (*Cyprinus carpio*) is one of the most widely cultivated exotic carp species in Nepal. It has high growth potential and adaptability to various environmental conditions (Khan et al. 2016; Yaqoob 2021). It is mainly cultured in semi-intensive polyculture system in Nepal though it also has potential to be cultured in intensive monoculture system (Kestmont 1995). The first import of German or scale carp (*Cyprinus carpio* var. *communis*) was done in 1955 from India while second import of Israeli or mirror carp (*Cyprinus carpio* var. *specularis*) was done in 1959 from Israel (PLFBCPRC 2021). Post import, no line improvement of Common carp in Nepal has been done to date. As a result, their growth and yield have been reported to decrease owing to the inbreeding depression (PLFBCPRC 2022). Considering this, Government of Nepal along with Food and Agriculture Organization imported new pure line Common carp in 2011/12 from China. Those pure line Common carp had been distributed to four centers namely Fishery Research Station, Pokhara; Fisheries Development Center (Now Pure Line Fish Breed Conservation and Promotion Resource Centre), Bhairahawa; Fisheries Development and Training Center (Now Fisheries Human Resource Development and Technology Validation Center), Janakpur; and Regional Agriculture Research Station, Tarahara. Since then, Pure Line Fish Breed Conservation and Promotion Resource Centre, Bhairahawa has been managing this pure line and distributing seeds to government and private

hatcheries. However, no scientific studies have been carried out to assess the growth performance of the pure line in Nepal (Labh et al. 2017; Shrestha 1999). This knowledge gap impedes the ability of fish farmers, researchers, and policymakers to make decisions regarding the selection of pure line Common carp for cultivation in Nepal. The present study was thus carried out to compare the growth and production performance of old stock and pure line Common carp fry and fingerlings at different stocking densities.

MATERIALS AND METHODS

Present study was carried out at Fisheries Development Centre, Geta, Kailali for a culture duration of 150 days from 4 May to 1 October 2021. The experiment was conducted in a 2×3 factorial design with two factors, i) old stock (G) and pure line (B) Common carp and ii) three stocking densities (20, 30 and 40 fry/m², indicated as T₂₀, T₃₀, and T₄₀ respectively) and all the treatments had three replicates. Altogether, 18 nylon hapas (1 m × 1 m × 1 m) were suspended in a pond of 300 m² (30 m × 10 m × 1 m) with the help of bamboo poles and stones as sinkers for proper positioning. The treatments were allocated randomly to each hapa. The treatment details are shown in Table 1.

Table 1: Experimental design

Treatment	Stocking density (fry/m ²)		
	T ₂₀	T ₃₀	T ₄₀
TG (Old stock)	G ₂₀	G ₃₀	G ₄₀
TB (Pure line)	B ₂₀	B ₃₀	B ₄₀

Fry of pure line was procured from Pure Line Fish Breed Conservation and Promotion Resource Center, Bhairahawa, Rupandehi whereas old stock was procured from the Fisheries Development Center, Geta, Kailali.

The average initial weight of the old stock fry was 1.1±0.1 g/fish while that of the pure line was 2.1±0.1 g/fish. They were stocked in different hapas depending on the stocking densities as per treatment. Commercial pellet diet (ABIS Acuaster, 32% CP) was fed to fish at a rate of 5% of body weight twice daily (10:00 AM and 3:00 PM). The feed adjustment was done monthly based on body weight gain.

Fish growth check was done monthly by sampling 30% of the total stocked fish. Hapas were removed from the pond and all fish were taken out, counted and weights were taken using top-pan balance. After taking weight, all fish were restocked in corresponding hapas according to treatments. Final harvesting was done on 1 October 2021.

The water quality parameters including temperature, dissolved oxygen (DO) and pH were recorded from pond in-situ every week in the morning between 09:00 to 10:00 AM using standard portable DO and pH meters.

Gross margin analysis was done to calculate the gross margin among different treatments. Benefit cost ratio (B:C ratio) was also calculated. All the calculations were based on current market price of the variables as well as products.

All collected data were entered in MS-Excel and analyses were done using SPSS (V 21.0). T-test was used to compare the means of different parameters among two stocks of Common carp. Similarly, to compare means among different stocking densities one way ANOVA was used followed

by Duncan's Multiple Range Test (DMRT). Alpha level was set at 0.05 for all comparisons, and all the means were expressed as mean $\pm$ SE except water quality parameters.

RESULTS

Water quality parameters

The weekly mean and range of different water quality parameters including water temperature, DO, and pH are shown in Table 2.

Table 2: Water quality parameters of pond during experimental period

Parameters	Mean $\pm$ SD	Range
Temperature ($^{\circ}$ C)	29.5 $\pm$ 1.5	26.4-31.6
DO (mg/L)	5.8 $\pm$ 0.5	4.8-6.8
pH	8.7	8.1-9.6

Growth and yield of old stock and pure line Common carp

The average stocking weight, stocking length and total stocking weight of pure line (T_B) common carp were significantly higher ($p<0.05$) than those of old stock (T_G) due to the unavailability of uniform-sized fish fry of both stocks. Similarly, the average harvesting weight, total harvesting weight, total weight gain, daily weight gain (DWG), specific growth rate (SGR), extrapolated gross fish yield (EGFY) and extrapolated net fish yield (ENFY) of pure line (T_B) were also significantly higher ($p<0.05$) than those of old stock (T_G) (Table 3).

Table 3: Growth and yield (mean $\pm$ SE) of old stock and pure line Common carp

Parameters	Old stock (T_G)	Pure line (T_B)	p-value
Average stocking weight (g/fish)	1.1 $\pm$ 0.1 ^b	2.1 $\pm$ 0.1 ^a	0.000
Average stocking length (cm/fish)	3.5 $\pm$ 0.1 ^b	4.9 $\pm$ 0.1 ^a	0.000
Total stocking weight (g/hapa)	33.4 $\pm$ 2.8 ^b	62.9 $\pm$ 4.6 ^a	0.000
Average harvesting weight (g/fish)	16.1 $\pm$ 1.4 ^b	21.9 $\pm$ 0.8 ^a	0.002
Average harvesting length (cm/fish)	10.5 $\pm$ 0.5 ^a	11.6 $\pm$ 0.3 ^a	0.053
Total harvested weight (g/hapa)	423.5 $\pm$ 29 ^b	602.7 $\pm$ 55.9 ^a	0.012
Total weight gain (g/hapa)	390.2 $\pm$ 27.2 ^b	539.9 $\pm$ 51.8 ^a	0.021
Average length gain (cm/fish)	7.0 $\pm$ 0.5 ^a	6.7 $\pm$ 0.3 ^a	0.657
DWG (g/fish/day)	0.10 $\pm$ 0.01 ^b	0.13 $\pm$ 0.01 ^a	0.007
SGR (%/day)	1.75 $\pm$ 0.05 ^b	1.55 $\pm$ 0.03 ^a	0.002
Survival rate (%)	92.3 $\pm$ 0.8 ^a	92.6 $\pm$ 0.8 ^a	0.812
EGFY (kg/100 m ² /y)	103.1 $\pm$ 7.1 ^b	146.7 $\pm$ 13.6 ^a	0.012
ENFY (kg/100 m ² /y)	94.9 $\pm$ 6.6 ^b	131.4 $\pm$ 12.6 ^a	0.021
AFCR	2.5 $\pm$ 0.1 ^a	2.5 $\pm$ 0.2 ^a	0.730

Mean values with similar superscript within a row are not significantly different at $p<0.05$.

Growth and yield of common carp at different stocking densities

The growth and yield of common carp reared at different stocking densities are shown in Table 4. The average harvesting length and the length gain of treatment T₂₀ were significantly higher ($p<0.05$) than those of treatments T₃₀ and T₄₀ with no significant difference ($p>0.05$) between T₃₀ and T₄₀. However, total harvest weight, total weight gain, EGFY and ENFY of T₄₀ were significantly higher ($p<0.05$) than T₂₀ and T₃₀ with no significant difference ($p>0.05$) among T₂₀ and T₃₀.

Table 4: Growth and yield (mean $\pm$ SE) of Common carp at different stocking densities

Parameters	T ₂₀	T ₃₀	T ₄₀	p-value
Average stocking weight (g/fish)	1.9 $\pm$ 0.3 ^a	1.5 $\pm$ 0.2 ^a	1.5 $\pm$ 0.2 ^a	0.420
Average stocking length (cm/fish)	4.2 $\pm$ 0.3 ^a	4.2 $\pm$ 0.3 ^a	4.2 $\pm$ 0.3 ^a	0.979
Total stocking weight (g/hapa)	38.2 $\pm$ 5.1 ^a	45.3 $\pm$ 7.3 ^a	60.8 $\pm$ 8.2 ^a	0.097
Average harvesting weight (g/fish)	22.2 $\pm$ 1.2 ^a	17.3 $\pm$ 2 ^a	17.5 $\pm$ 1.6 ^a	0.095
Average harvesting length (cm/fish)	12.2 $\pm$ 0.3 ^a	10.5 $\pm$ 0.5 ^b	10.5 $\pm$ 0.5 ^b	0.021
Total harvested weight (g/hapa)	410.2 $\pm$ 24.7 ^b	471.6 $\pm$ 55.4 ^b	657.6 $\pm$ 63.4 ^a	0.009
Total weight gain (g/hapa)	372.1 $\pm$ 22.3 ^b	426.3 $\pm$ 49.3 ^b	596.7 $\pm$ 56.2 ^a	0.008
Average length gain (cm/fish)	8.0 $\pm$ 0.4 ^a	6.3 $\pm$ 0.3 ^b	6.3 $\pm$ 0.3 ^b	0.006
DWG (g/fish/day)	0.14 $\pm$ 0.01 ^a	0.11 $\pm$ 0.01 ^a	0.11 $\pm$ 0.01 ^a	0.086
SGR (%/day)	1.66 $\pm$ 0.08 ^a	1.64 $\pm$ 0.07 ^a	1.65 $\pm$ 0.05 ^a	0.975
Survival rate (%)	92.5 $\pm$ 1.1 ^a	91.1 $\pm$ 0.7 ^a	93.8 $\pm$ 0.9 ^a	0.155
EGFY (kg/100 m ² /yr)	99.8 $\pm$ 6 ^b	114.8 $\pm$ 13.5 ^b	160 $\pm$ 15.4 ^a	0.009
ENFY (kg/100 m ² /yr)	90.5 $\pm$ 5.4 ^b	103.7 $\pm$ 12 ^b	145.2 $\pm$ 13.7 ^a	0.008
AFCR	2.5 $\pm$ 0.2 ^a	2.6 $\pm$ 0.2 ^a	2.4 $\pm$ 0.2 ^a	0.686

Mean values with similar superscript within a row are not significantly different at $p<0.05$.

Growth and yield of fish in different treatments

The growth and production parameters of common carp in different treatments considering both stocks and stocking densities together are shown in Table 6. The average harvesting weight and average harvesting length of common carp in G₂₀, B₂₀, B₃₀ and B₄₀ were significantly higher ($p<0.05$) than G₃₀ and G₄₀. The total harvested weight, total weight gain, EGFY and ENFY of B₄₀ were significantly higher ($p<0.05$) than all other treatments showing a decreasing pattern in B₃₀, G₄₀, B₂₀, G₃₀, and G₂₀. Conversely, the average length gain of G₂₀ was significantly higher ($p<0.05$) than all other treatments except B₂₀ while that of B₂₀ was not significantly different ($p>0.05$) than any other treatments. The DWG of G₂₀, B₂₀, B₃₀, and B₄₀ were significantly higher ($p<0.05$) than the DWG of G₃₀ and G₄₀ while the SGR of G₂₀ was significantly higher ($p<0.05$) than that of B₂₀, B₃₀, and B₄₀.

Table 6: Growth and yield (mean $\pm$ SE) of old stock and pure line common carp in different treatments during experiment

Parameters	G ₂₀	G ₃₀	G ₄₀	B ₂₀	B ₃₀	B ₄₀	p-value
Average stocking weight (g/fish)	1.4 $\pm$ 0.2 ^c	1.0 $\pm$ 0.1 ^d	1.1 $\pm$ 0.1 ^{cd}	2.5 $\pm$ 0.1 ^a	2.0 $\pm$ 0.1 ^b	2.0 $\pm$ 0.1 ^b	0.000
Average stocking length (cm/fish)	3.5 $\pm$ 0.2 ^b	3.5 $\pm$ 0.1 ^b	3.6 $\pm$ 0.2 ^b	4.9 $\pm$ 0.1 ^a	4.9 $\pm$ 0.1 ^a	4.9 $\pm$ 0.1 ^a	0.000
Total stocking weight (g/hapa)	27.3 $\pm$ 3.2 ^d	29.7 $\pm$ 1.9 ^d	43.1 $\pm$ 3.3 ^c	49.0 $\pm$ 2.2 ^c	61 $\pm$ 4.1 ^b	78.6 $\pm$ 3.5 ^a	0.000
Average harvesting weight (g/fish)	21.1 $\pm$ 1.1 ^a	13 $\pm$ 1.7 ^b	14.1 $\pm$ 0.7 ^b	23.2 $\pm$ 2.2 ^a	21.5 $\pm$ 0.4 ^a	20.9 $\pm$ 1 ^a	0.001
Average harvesting length (cm/fish)	12.2 $\pm$ 0.4 ^a	9.7 $\pm$ 0.5 ^b	9.6 $\pm$ 0.3 ^b	12.1 $\pm$ 0.6 ^a	11.2 $\pm$ 0.5 ^a	11.5 $\pm$ 0.4 ^a	0.003
Total harvested weight (g/hapa)	392.8 $\pm$ 17.7 ^d	355.3 $\pm$ 42.2 ^d	522.5 $\pm$ 17.1 ^{abc}	427.7 $\pm$ 49.3 ^{cd}	587.9 $\pm$ 5.6 ^b	792.6 $\pm$ 39.6 ^a	0.000
Total weight gain (g/hapa)	365.4 $\pm$ 14.8 ^d	325.6 $\pm$ 44.1 ^d	479.4 $\pm$ 18.5 ^{bc}	378.7 $\pm$ 47.2 ^{cd}	526.9 $\pm$ 9.6 ^b	714.1 $\pm$ 41.1 ^a	0.000
Average length gain (cm/fish)	8.7 $\pm$ 0.4 ^a	6.3 $\pm$ 0.6 ^b	6.0 $\pm$ 0.4 ^b	7.3 $\pm$ 0.5 ^{ab}	6.4 $\pm$ 0.5 ^b	6.6 $\pm$ 0.5 ^b	0.016
DWG (g/fish/day)	0.13 $\pm$ 0.01 ^a	0.08 $\pm$ 0.01 ^b	0.09 $\pm$ 0.00 ^b	0.14 $\pm$ 0.01 ^a	0.13 $\pm$ 0.00 ^a	0.13 $\pm$ 0.01 ^a	0.001
SGR (%/day)	1.83 $\pm$ 0.05 ^a	1.71 $\pm$ 0.13 ^{ab}	1.72 $\pm$ 0.07 ^{ab}	1.50 $\pm$ 0.03 ^b	1.58 $\pm$ 0.06 ^b	1.57 $\pm$ 0.05 ^b	0.060

Parameters	G ₂₀	G ₃₀	G ₄₀	B ₂₀	B ₃₀	B ₄₀	p- value
Survival rate (%)	93.3±1.7 ^a	91.1±1.1 ^a	92.5±1.4 ^a	91.7±1.7 ^a	91.1±1.1 ^a	95.0±0.0 ^a	0.304
EGFY (kg/100 m ² /yr)	95.6±4.3 ^d	86.5±10.3 ^d	127.1±4.2 ^{bc}	104.1±12.0 ^{cd}	143.1±1.4 ^b	192.9±9.6 ^a	0.000
ENFY (kg/100 m ² /yr)	88.9±3.6 ^d	79.2±10.7 ^d	116.7±4.5 ^{bc}	92.1±11.5 ^{cd}	128.2±2.3 ^b	173.8±10 ^a	0.000
AFCR	2.3±0.1 ^a	2.6±0.3 ^a	2.5±0.1 ^a	2.8±0.5 ^a	2.6±0.1 ^a	2.3±0.4 ^a	0.791

Mean values with similar superscript within a row are not significantly different at $p < 0.05$.

Gross margin analysis

Gross margin analysis of common carp fingerlings production of both stocks is shown in Table 7. The average feed price and total variable cost of T_B were significantly higher ($p < 0.05$) than those of T_G. Similarly, the gross return, gross margin and B:C ratio of T_G were significantly lower ($p < 0.05$) than that of T_B.

Table 7: Gross margin analysis of old stock and pure line Common carp fingerling production (NRs. 000's/100 m², mean±SE) in 150 days.

Particulars	Old stock (T _G)	Pure line (T _B)	p-value
Installation cost	6.00±0.00	6.00±0.00	
Seed	0.75±0.07 ^a	0.75±0.07 ^a	1.000
Feed	6.78±0.66 ^b	9.98±0.78 ^a	0.006
Total variable cost	13.53±0.70 ^b	16.73±0.84 ^a	0.010
Gross return	16.94±1.16 ^b	24.11±2.24 ^a	0.012
Gross margin	3.41±0.55 ^b	7.38±1.70 ^a	0.041
B:C ratio	1.24±0.03 ^b	1.43±0.09 ^a	0.036

Mean values with similar superscript within a row are not significantly different at $p < 0.05$.

The gross margin analysis of common carp fingerlings production at different stocking densities is shown in Table 8. The average feed cost of T₄₀ was significantly higher ($p < 0.05$) than T₂₀ while at par ($p > 0.05$) with T₃₀ while the total variable cost of T₄₀ was significantly higher ($p < 0.05$) than T₂₀ and T₃₀. Similarly, the gross return and gross margin of T₄₀ were significantly higher ($p < 0.05$) than T₂₀ and T₃₀. The B:C ratio of T₄₀ was significantly higher ($p < 0.05$) than T₂₀ while at par ($p > 0.05$) with T₃₀.

Table 8: Gross margin analysis of common carp fingerlings production at different stocking densities (NRs. 000's/100 m², mean±SE) in 150 days

Particulars	T ₂₀	T ₃₀	T ₄₀	p-value
Installation cost	6.00±0.00	6.00±0.00	6.00±0.00	
Seed	0.50±0.00	0.75±0.00	1.00±0.00	
Feed	7.10±0.69 ^b	7.66±1.23 ^{ab}	10.37±0.90 ^a	0.065
Total variable cost	13.60±0.69 ^b	14.41±1.23 ^b	17.37±0.90 ^a	0.035
Gross return	16.41±0.99 ^b	18.86±2.22 ^b	26.30±2.54 ^a	0.009
Gross margin	2.81±0.37 ^b	4.45±1.09 ^b	8.93±2.16 ^a	0.021
B:C ratio	1.2±0.02 ^b	1.29±0.06 ^{ab}	1.51±0.12 ^a	0.042

Mean values with similar superscript within a row are not significantly different at $p < 0.05$.

The gross margin analysis of common carp fingerlings production among different treatments is shown in Table 9. The feed cost and the total variable cost in B₄₀ were significantly higher ($p < 0.05$) than all other treatments except B₃₀. Similarly, those of B₃₀ was significantly higher ($p < 0.05$) than treatments G₂₀ and G₃₀ while at par ($p > 0.05$) with G₄₀, and B₂₀. The gross return of B₄₀ was significantly higher ($p < 0.05$) than all other treatments while that of B₃₀ was significantly higher ($p < 0.05$) than all other treatments except G₄₀. The gross return of G₂₀ and G₃₀ were significantly

lower ($p<0.05$) than all other treatments except B₂₀. However, the gross margin and B:C ratio of B₄₀ were significantly higher ($p<0.05$) than all other treatments with no significant difference ($p>0.05$) among those treatments.

Table 9: Gross margin analysis of Common carp fingerlings production in different treatments (NRs. 000's/100 m², mean±SE)

Particulars	G ₂₀	G ₃₀	G ₄₀	B ₂₀	B ₃₀	B ₄₀	p-value
Installation cost	6.00±0.00	6.00±0.00	6.00±0.00	6.00±0.00	6.00±0.00	6.00±0.00	
Seed	0.50±0.00	0.75±0.00	1.00±0.00	0.50±0.00	0.75±0.00	1.00±0.00	
Feed	6.31±0.57 ^{cd}	5.21±1.17 ^d	8.81±0.25 ^{bc}	7.88±1.21 ^{bcd}	10.11±0.41 ⁱ	11.94±1.25 ^j	0.002
Total variable cost	12.81±0.57 ^c	11.96±1.17 ^c	15.81±0.25 ^t	14.38±1.21 ^{bc}	16.86±0.41 ⁱ	18.94±1.25 ^j	0.001
Gross return	15.71±0.71 ^d	14.21±1.69 ^d	20.90±0.70 ^{bc}	17.11±1.97 ^{cd}	23.52±0.22	31.70±1.58 ^j	0.000
Gross margin	2.90±0.31 ^b	2.25±0.87 ^b	5.09±0.73 ^t	2.72±0.77 ^b	6.65±0.62	12.77±2.8 ^j	0.001
B:C ratio	1.22±0.02 ^b	1.19±0.06 ^b	1.32±0.05 ^t	1.18±0.03 ^b	1.4±0.05	1.7±0.19 ^j	0.010

Mean values with similar superscript within a row are not significantly different at $p<0.05$.

DISCUSSION

Water quality parameters

The water quality parameters including water temperature, pH and DO remain within acceptable range during experimental period for common carp growth as reported in previous studies (Chakrabarti and Sharma 1998; Ghanbari et al. 2012; Mallya 2007; Abbas 2006; Iqbal and Shah 2014; Ali et al. 2022).

Growth and yield

The overall growth and yield of pure line common carp was found to be significantly better ($p<0.05$) than the old stock. This might be due to genetic factors to play significant role in the growth and survival of common carp (Mráz and Pickova 2011) which might be due to desirable growth characteristics like faster growth rates, higher feed conversion efficiency and better disease resistance in pure line which might have been developed through selective breeding program in China (Abdelsalam and Piačková 2022; Chen et al. 2022a). The increased growth rate was very well reflected in the increased extrapolated gross fish yield by 41.7% in pure line compared to old stock.

The stocking density found to have no profound effect on growth performance of fish. In general, fish exhibit depressed growth at higher stocking densities due to overcrowding leading to competition for resources and increased stress levels (Ruane et al. 2002; Enache et al. 2011). No such effects were observed in the present study which can be attributed to the smaller size of fish. The total weight gain, EGFY and ENFY were found to be significantly higher ($p<0.05$) in treatments with highest stocking density, it could be attributed to the higher number of fish stocked and thus survived.

In overall comparison, the treatments stocked with pure line showed better growth and yield than the old stock. The significant difference in total stocking weight can be attributed to difference in the stocking density. The total weight gain in B₄₀ was significantly higher compared to all other treatments which can be attributed to the combined effect of higher stocking density and survival (Murakaeva et al. 2003). Though higher stocking density may lead to lower DWG, it was found that the DWG of old stock at lower density was comparable with the DWG of pure line at higher stocking density. This result showed that the pure line had faster growth (Mráz and Pickova 2011; Abdelsalam and Piačková 2022; Chen et al. 2022b) and that can suppress the effect of crowding

(Bakos and Gorda, 1995; Ruane et al. 2002; Enache et al. 2011). Similarly, the significantly higher EGFY and ENFY in treatment with higher stocking density of pure line can be attributed to the significantly higher total weight gain. In overall, the production parameters of fish in treatment stocked with pure line at stocking rate of 40 fry/m² was better compared to old stock at lower stocking density.

Gross margin analysis

The financial analysis of present study showed that the total variable cost for pure line treatment (T_B) was significantly higher ($p < 0.05$) than that for old stock (T_G) which can be easily attributed to significantly higher ($p < 0.05$) feed cost. Higher feed cost for pure line was due to ration adjustment with growth and pure line fish had better growth fish and feed conversion efficiency (Abdelsalam and Piačková 2022; Chen et al. 2022b). Alongside, the gross return, gross margin and the B:C ratio of pure line were significantly higher ($p < 0.05$) than the old stock which can again be attributed to higher total weight gain and fish yield. Hence, rearing the fingerlings of pure line could be a profitable venture than the rearing of old stock common carp. The B:C ratio of pure line was around 15.3% higher compared to that of old stock meaning 15% more profit can be earned with pure line fingerlings. The feed cost and total variable cost were found to be significantly higher ($p < 0.05$) in high stocking density than low stocking density due to increased biomass of fish and ration adjustment based on biomass. The gross return, gross margin and B:C ratio of B_{40} were significantly higher ($p < 0.05$) than all other treatments with better growth and yield.

CONCLUSION

In Nepal, common carp has been playing a significant role to increase production and productivity in carp polyculture system. The results of present study clearly indicated that the pure line common carp had better growth performance and economic return compared to old stock common carp. In overall, the pure line common carp at higher density of 40 fish/m² resulted in better yield and gross margin as well as B:C ratio. Increased stocking density did not decrease the overall growth and yield of common carp indicated stocking density can be increased further.

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REFERENCES

- Abbas, H.H. (2006). Acute toxicity of ammonia to Common carp fingerlings (*Cyprinus carpio*) at different pH levels. Pakistan Journal of Biological Sciences, 9(12): 2215-2221. <https://doi.org/10.3923/pjbs.2006.2215.2221>.
- Abdelsalam, E.E.E., & Piačková, V. (2022). Carp edema virus host selection and interaction, and potential factors affecting its introduction to the Common carp population, distribution, and survival. Aquaculture, 563(2): 739009. <https://doi.org/10.1016/j.aquaculture.2022.739009>.

- Ali, B., Mishra, A., & Mishra, A. (2022). Effects of dissolved oxygen concentration on freshwater fish: A review. *International Journal of Fisheries and Aquatic Studies*, 10(4): 113–127. <https://doi.org/10.22271/fish.2022.v10.i4b.2693>.
- Bakos, J., & Gorda, S. (1995). Genetic improvement of Common carp (*Cyprinus carpio*) strains using intraspecific hybridization. *Aquaculture*, 129(1–4): 183–186. [https://doi.org/10.1016/0044-8486\(94\)00245-J](https://doi.org/10.1016/0044-8486(94)00245-J).
- Chakrabarti, R., & Sharma, J.G. (1998). Influence of management protocols on carp growth under nursery conditions: Relative importance of food and water quality. *Aquaculture International*, 6: 293–301. <https://doi.org/10.1023/A:1009203831411>.
- Chen, J., Sun, D., Cui, H., Rao, C., Li, L., Guo, S., Yang, S., Zhang, Y., & Cao, X. (2022a). Toxic effects of carbon quantum dots on the gut–liver axis and gut microbiota in the Common carp *Cyprinus carpio*. *Environmental Science: Nano*, 9(1): 173–188. <https://doi.org/10.1039/d1en00651g>.
- Chen, L., Xu, J., Sun, X., & Xu, P. (2022b). Research advances and future perspectives of genomics and genetic improvement in allotetraploid Common carp. *Reviews in Aquaculture*, 14(2): 957–978. <https://doi.org/10.1111/raq.12636>.
- Enache, I., Cristea, V., Ionescu, T., & Ion, S. (2011). The influence of stocking density on the growth of Common carp, *Cyprinus carpio*, in a recirculating aquaculture system. *Aquaculture, Aquarium, Conservation & Legislation*, 4(2): 146–153.
- Ghanbari, M., Jami, M., Domig, K.J., & Kneifel, W. (2012). Long-term effects of water pH changes on hematological parameters in the Common carp (*Cyprinus carpio* L.). *African Journal of Biotechnology*, 11(13): 3153–3159. <https://doi.org/10.5897/AJB10.1244>.
- Iqbal, J., & Shah, M.H. (2014). Study of seasonal variations and health risk assessment of heavy metals in *Cyprinus carpio* from Rawal Lake, Pakistan. *Environmental Monitoring and Assessment*, 186(4): 2025–2037. <https://doi.org/10.1007/s10661-013-3515-6>.
- Kestemont, P. (1995). Different systems of carp production and their impacts on the environment. *Aquaculture*, 129(1–4): 347–372. [https://doi.org/10.1016/0044-8486\(94\)00292-V](https://doi.org/10.1016/0044-8486(94)00292-V).
- Khan, M.N., Shahzad, K., Chatta, A., Sohail, M., Piria, M., & Treer, T. (2016). A review of introduction of Common carp *Cyprinus carpio* in Pakistan: Origin, purpose, impact and management. *Croatian Journal of Fisheries*, 74(2): 71–80. <https://doi.org/10.1515/cjf-2016-0016>.
- Labh, S.N., Kayastha, B.L., Shakya, S.R., Kushwaha, M.P., Vaidya, S.R., Chitrakar, P., & Dhital, K.S. (2017). Present status and future prospectives of freshwater fisheries in Nepal: A short overview. *International Journal of Fisheries and Aquatic Studies*, 5(3): 95–97.
- Mallya, Y.J. (2007). The effects of dissolved oxygen on fish growth in aquaculture. The United Nations University. Fisheries Training Programme, Final Project.
- Mráz, J., & Pickova, J. (2011). Factors influencing fatty acid composition of Common carp (*Cyprinus carpio*) muscle. *Neuroendocrinology Letters*, 32(Suppl 2): 3–8.
- Murakaeva, A., Kohlmann, K., Kersten, P., Kamilov, B., & Khabibullin, D. (2003). Genetic characterization of wild and domesticated Common carp (*Cyprinus carpio* L.) populations from Uzbekistan. *Aquaculture*, 218(1-4): 153–166. [https://doi.org/10.1016/S0044-8486\(03\)00005-X](https://doi.org/10.1016/S0044-8486(03)00005-X).
- PLFBCPRC. (2021). Annual Progress and Technical Report 2077-78. Pure Line Fish Breed Conservation and Promotion Resource Center, Bhairahawa, Nepal. 20p.
- PLFBCPRC. (2022). Pure line brood distribution. Pure Line Fish Breed Conservation and Promotion Resource Center. Retrieved from <https://plfbcprc.gov.np/document/pure-line-brood-distribution?language=en>.

- Ruane, N.M., Carballo, E.C., & Komen, J. (2002). Increased stocking density influences the acute physiological stress response of Common carp *Cyprinus carpio* (L.). *Aquaculture Research*, 33(10): 777-784. <https://doi.org/10.1046/j.1365-2109.2002.00717.x>.
- Shrestha, J. (1999). Coldwater fish and fisheries in Nepal. In: Petr A. (eds.) *Fish and Fisheries at Higher Altitudes. Asia*. FAO Fisheries Technical Paper, 385: 13–40.
- Yaqoob, S. (2021). A Review of Structure, Origin, Purpose & Impact of Common carp (*Cyprinus carpio*) in India. *Annals of the Romanian Society for Cell Biology*, 25(6): 34-47.



SOME SUCCESSFUL ASPECTS OF INTERNATIONAL TRENDS IN FISHERY AND FISH CULTURE DEVELOPMENT IN NEPAL

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ABSTRACT

Fishing and fishery practices are as old as humanity while aquaculture was known to be started by FAN Li in fifth century BCE from China. Modern, science-based worldwide development of inland fishery and fish culture started in the middle of the 19th century. One of the effects of these processes was that international trends developed which were studied, considered, adapted and implemented according to the needs and requirements of each country worldwide. In Nepal the development of modern fishery and fish culture started in the 1950's, where in the light of international trends the development of both was definitely successful, still should be further fine-tuned with focus on: (1) Research in advanced fishery enhancement in natural waters, (2) Piloting fishery management techniques, (3) Strict implementation of aquatic biodiversity conservation related acts, including a more consistent, traditional-fishers-friendly enforcement of fisheries controlling acts and regulations, (4) Promotion of household fish nurseries, (5) Enhancing vocational and higher fishery education, (6) Training of fish farmers, (7) Collaboration and coordination among education, research, extension institutions and among the three levels of government for fishery and aquaculture development.

Key words: Sustainable fishery, fish culture systems, fish production technologies, vocational education, extension.

INTRODUCTION

There are five well distinct physiographical zones of Nepal. All these five main zones of the country have a different climate, ranging from tropical through subtropical, warm/cool temperate and alpine, up to arctic (Thapa and Thapa 1969; Gurung 2016; Shrestha 2019).

From east to west there are four large, seven medium and many small rivers across the country which all end in the Ganges. The fish fauna of the country is rich and diverse, reported to be a total of 252 fish species. including 236 native (out of them 17 endemic) and 16 exotic species (Shrestha 2019).

Aquaculture is a relatively new activity in Nepal, of which the start can be dated back to the early 1950's (Labh et al. 2017). In the mid 1950's a survey of the fisheries of Nepal was completed by United States Overseas Mission (USOM). The survey compiled by Taft in 1955 reviewed both the major influencing factors and the actual state of fisheries (both fishery and fish culture) in Nepal. Accordingly:

- The major influencing factors of fisheries were identified as; (1) Precipitation is between 1905 and 2500 mm which is concentrated for four months (Jun-Sep.). (2) Positions and north-south flow of all major river systems, the regular floodings and the direct connection to the Ganges. (3) Small number of natural lakes and absence of water reservoirs. (4) The existence of a varied and adequate natural fish fauna. (5) There are no religious objections of consuming fish by most of the population. (6) Low economic and social status of fishing population.
- The actual state of fisheries was diagnosed as; (1) The use of fishing equipment (trap, cast nets, hooks) are restricted to those made/can be made from locally available materials. (2) Lack of transport facilities and preservation materials and techniques of captured fish. (3) Village ponds are widely found throughout the country which function and are fished as natural waters. (4) Though selected fish species are considered sacred and are kept in temple pools, but fish farming as such is practically unknown. (5) That time the government employed only one Fisheries Development Officer.

The present paper aims the concise systematic review of the present state and field practices of both fishery and fish culture, with focus on key national factors and those international trends, which have shaped and determined the fishery and aquaculture in Nepal.

WATER RESOURCES OF FISHERY AND AQUACULTURE

Nepal is rich in water resources. These include rivers, streams, lakes, ponds, reservoirs, swamps etc. There are four river systems, from east to west; the Koshi, Gandaki, Karnali and Mahakali. Besides there are seven medium and many small rivers which cover 94% of total water area (Thapa and Thapa 1969). According to water carrying capacities, three main groups of rivers are distinguished (Thapa and Thapa 1969):

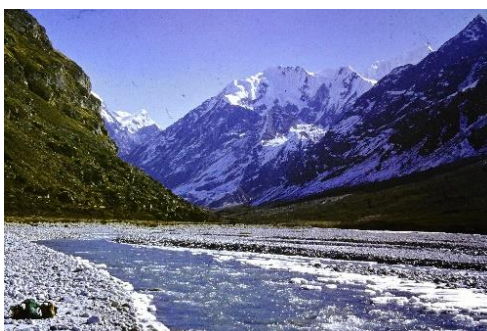
- Major or first grade rivers: These rivers have a permanent source of snow and glacier, hence are full of water all the year around. These rivers are the Koshi, Gandaki, Karnali and Mahakali and their main tributaries.
- Medium or second-grade rivers: These are the Mechi, Kankai, Kamala, Bagmati, Tinau, Rapti and Babai. These originate in high mountains or Mahabharat. These are perennial, have the water all the times, but the volume of water during dry season remains low.
- Small or third-grade rivers: These are numerous and rather short in length. These originate in Siwalik range and are highly seasonal – ephemeral.



Figure 1: Fishers using traditional gears (above). One of the sacred ponds and village ponds mentioned by Taft in relation to potential initiation of fish culture in 1955 (below).



(Photos by Elek Woynarovich)



(Photo by Elek Woynarovich)



(Photo by Andras)

Figure 2: Where rivers rise (Left). The confluence near to the Terai where Narayani starts (Right).

The total number of streams and rivers is about 6000 and they have an estimated total area of 395000 ha (Gubhaju 2002; Shrestha 2002a; Shrestha et al. 2002; Swar 2002; Gautam and Sapkota 2023). Most of the rivers rise in the Himalayas and the Midland Mountain Zone. They flow across the country with curves in north-south direction and drain into the Ganges or into one of its tributaries.

In addition to the rivers there are 5358 lakes and their total area is 5000 ha (Bhuju et al. 2010; Gautam and Sapkota 2023). According to Shrestha et al. (2002a), the major lakes are as follows:

- Mountain lakes (total area: 1180 ha) – Rara Tal (1 000 ha) and Shey-Phoksundo Tal (180 ha), There are two mountain lakes Tilicho (480 ha) and Gosaikunda (13.8 ha) in which there are no fish.
- Mid-hill lakes (total area: 1114 ha) – Phewa Tal (523 ha), Begnas Tal (328 ha), Rupa Tal (135 ha), Deepang Tal (20 ha), Khaste Tal (16 ha), Gunde Tal 9 ha), Maidee Tal (8 ha) and Syarpu Tal (75 ha).
- Low-land lakes (total area: 1013 ha) – Mahadev Tal (50 ha), Rupia Tal (50 ha), Gadhbhijala Tal (300 ha), Ghodaghodi Tal (138 ha), Nakhrodi Tal (70 ha), Badhaiya Tal (105 ha), Sakhunia Tal (50 ha), BudhiTal (50 ha), Gaindhawa Tal (50 ha), Beesh Hazar Tal (100 ha) and Halkhoria Tal (50 ha).

There are 8 major reservoirs in the country. Their total area is 1500 ha. These are the Jagadishpur, Trishuli, Marshyangdi, Kulekhani, Kali Gandaki, Saptakoshi, Andikhola and Panauti (Shrestha et al. 2002; Swar 2002; Shrestha 2019).

Village ponds, irrigation canals, irrigated paddy fields, marginal swamps and highway side ditches cum ditches are about 14137 ha, 3160 ha, 398000 ha, 6500 ha, 12500 ha and 262 ha, respectively (Gautam and Sapkota 2023). As outlined in the subsequent chapters these two types of water resources can facilitate either culture-based fishery (CBF) or pond culture. Even intensive fish culture can be practiced in these water bodies provided that the quantity and quality of water remain suitable throughout the season which is usually restricted to the monsoon months.

FISHERY

Fishery, i.e., fishing in the natural waters has mainly been small-scale, primarily for subsistence and secondly for sale, retains a longtime tradition in Nepal. Before the availability and wide-range use of modern, but low quality, relatively cheap gears, the families of fishing communities made their gears

(traps, nets, hooks) and equipment from locally available materials (bamboo, wicker, giant nettle (*Girardinia diversifolia*), wire, etc.). The number and fishing efficiency of such gears were proportional to the type, number and size of fish captured, hence traditional fishery ensured the sustainable fishery use and exploitation of the waters.

Similar to other countries, equally neighboring and faraway located ones, the widespread use of modern, more effective fishing gears, which together with the increased population and demand for fish, as well as the unfavorable environmental changes in the natural waters resulted in overfishing, even drastic reduction of the size and population of commercially valuable fish species. In order to slow down and stop the unfavorable tendencies sustainable enhancement in the fishery of natural waters became the prime objective also in Nepal as early as the late 1970's and early 1980's (Shrestha 2019; Dhakal et al. 2022).

Fishery enhancement

Inland fishery and its enhancement have had a special status in most of the countries throughout the continents for centuries. The fishery of natural inland waters (i.e., of rivers, canals, lakes and water reservoirs) is far beyond its actual economic importance. Mainly because of sharing the water resources with power generation, irrigation and rural/angling tourism, fishery has an integral part and role in rural life and development.

It was a world-wide tendency that the aquatic environment was altered due to flood control, regulation and damming of rivers, construction of water canals and reservoirs, dredging for construction materials and discharge of sewage. These often-drastic modifications of the aquatic ecosystem also effected both qualitatively and quantitatively the fish fauna. In addition, the ever-increasing demand and competition for the water resources with irrigation often suppressed interest on fishery. The reasons listed called for and justified the need for fishery enhancement measures worldwide.

Though in Nepal the development and enhancement of fishery have started later than in other countries, still its history went through a similar development process. This included mapping, research and conservation of fish fauna, as well as the technical and administrative management of the fishery. Consequently, research of the fish fauna including the accurate systematization and characterization of the fish species has always been in the focus (Shrestha 2019). Therefore, the fish fauna of Nepal is well known by today. Because the rivers rise and flow through the different climate zones, from alpine to practically tropical one, Nepal has a very rich and diverse fish fauna, which is typical of and characteristics to the upper, middle and lower courses of the rivers these fishes occupy. Therefore, along the long profile of rivers there are a wide range of economically and/or ecologically important native cold-water, warm-water and tropical fish species.

Since 1955, when only 94 fish species were listed (Taft 1955), by today practically the entire fish fauna of Nepal, a total of 252 fish species has scientifically systematized, described and presented by Shrestha (2019) in a milestone publication, based on field work and published literature. It is entitled "Ichthyology of Nepal – A Study of Fishery of the Himalayan Waters". According to this publication 93.7% and 6.7% of the fish species are native and endemic, respectively and it is only 6.3% of the fish fauna which were introduced into the waters of Nepal.

Though conservation of fish fauna considers all fish species equally important, in addition to the conservation status, modern fishery enhancement and management explicitly focus on the expectable

final size of adult fish. In Table 1 findings and opinion of selected authors are summarized on fish species found important for fisheries and fish culture.

Table 1: List of most important fish species, their conservation status, present and potential economic role in the fishery and fish culture in Nepal

Conservation status and species	Size category (cm)	Endemic fishes ¹	Fishes for fishery ²	Game fishes under pressure ³	Native fishes propagated artificially ⁴	Fishes for present fish culture ⁵	Fishes for future fish culture ⁶
01 Common (C)		0	2	7	3	3	11
<i>Channa marulius</i> ^{2, 3 and 6}	40-50		1	1			1
<i>Channa striata</i> ⁶	30-40						1
<i>Bangana dero</i> ^{3 and 4}	> 50			1	1		
<i>Cirrhinus mrigala mrigala</i> ^{3 and 5}	> 50			1		1	
<i>Garra gotyla gotyla</i> ⁶	10-20						1
<i>Labeo calbasu</i> ⁴	> 50				1		
<i>Labeo catla</i> ^{3 and 5}	> 50			1		1	
<i>Labeo dyocheilus</i> ⁶	10-20						1
<i>Labeo gonius</i> ⁶	> 50						1
<i>Labeo rohita</i> ^{3 and 5}	> 50			1		1	
<i>Schizothorax richardsonii</i> ^{2 and 3}	> 50		1	1			
<i>Barilius bendelisis</i> ⁶	10-20						1
<i>Heteropneustes fossilis</i> ⁴	20-30				1		
<i>Eutropiichthys goongwaree</i> ⁶	20-30						1
<i>Ompok bimaculatus</i> ⁶	30-40						1
<i>Wallago attu</i> ^{3 and 6}	> 50			1			1
<i>Macrognathus aral</i> ⁶	30-40						1
<i>Mastacembelus armatus</i> ⁶	> 50						1
02 Lower Risk - Least Concern (UN)		2	2	14	1	0	10
<i>Botia lohachata</i> ⁶	10-20						1
<i>Cirrhinus reba</i> ³	20-30			1			
<i>Cyprinion semiplotum</i> ³	> 50			1			
<i>Garra annandalei</i> ⁶	10-20						1

Conservation status and species	Size category (cm)	Endemic fishes ¹	Fishes for fishery ₂	Game fishes ³ under pressure	Native fishes propagated artificially ⁴	Fishes for present fish culture ⁵	Fishes for future fish culture ⁶
<i>Garra nepalensis</i> ¹	< 10	1					
<i>Labeo angra</i> ³	> 50			1			
<i>Labeo pangusia</i> ⁴	> 50				1		
<i>Psilorhynchus nudithoracicus</i> ¹	< 10	1					
<i>Chitala chitala</i> ^{3 and 6}	20-30			1			1
<i>Notopterus notopterus</i> ^{3 and 6}	20-30			1			1
<i>Clupisoma garua</i> ^{2, 3 and 6}	> 50		1	1			1
<i>Rita rita</i> ³	> 50			1			
<i>Sperata aor</i> ^{3 and 6}	> 50			1			1
<i>Sperata seenghala</i> ^{3 and 6}	30-40			1			1
<i>Pangasius pangasius</i> ³	> 50			1			
<i>Eutropiichthys vacha</i> ^{3 and 6}	20-30			1			1
<i>Bagarius bagarius</i> ^{2 and 3}	> 50		1	1			
<i>Bagarius yarrellii</i> ^{3 and 6}	> 50			1			1
<i>Monopterusuchia</i> ^{3 and 6}	> 50			1			1
03 Conservation dependent and rare (CDR)		4	1	1	0	0	0
<i>Schizothorax esocinus</i> ^{2 and 3}	10-20		1	1			
<i>Schizothorax macrophthalmus</i> ¹	10-20	1					
<i>Schizothorax nepalensis</i> ¹	20-30	1					
<i>Schizothorax raraensis</i> ¹	40-50	1					
<i>Myersglanis blythii</i> ¹	< 10	1					
04 Data deficient – Pristine Rare Ornamental (PRO)		9	1	1	0	0	0
<i>Neoanguilla nepalensis</i> ¹	< 10	1					
<i>Balitora eddsi</i> ¹	< 10	1					
<i>Raiamas bola</i> ^{2 and 3}	30-40		1	1			
<i>Turcinoemacheilus himalaya</i> ¹	< 10	1					

Conservation status and species	Size category (cm)	Endemic fishes ¹	Fishes for fishery ²	Game fishes under pressure ³	Native fishes propagated artificially ⁴	Fishes for present fish culture ⁵	Fishes for future fish culture ⁶
<i>Psilorhynchus nepalensis</i> ¹	< 10	1					
<i>Batasio macronotus</i> ¹	< 10	1					
<i>Pseudecheneis crassicauda</i> ¹	10-20	1					
<i>Pseudecheneis eddsi</i> ¹	10-20	1					
<i>Pseudecheneis serracula</i> ¹	10-20	1					
<i>Pseudolaguvia nepalensis</i> ¹	20-30	1					
06 Endangered (EN)		0	2	2	2	0	0
<i>Tor putitora</i> ^{2, 3 and 4}	> 50		1	1	1		
<i>Tor tor</i> ^{2, 3 and 4}	> 50		1	1	1		
08 Vulnerable (VU)		0	3	4	4	0	1
<i>Anguilla bengalensis bengalensis</i> ^{2, 3 and 6}	> 50		1	1			1
<i>Chagunius chagunio</i> ^{3 and 4}	10-20			1	1		
<i>Neolissochilus hexagonolepis</i> ^{2, 3 and 4}	> 50		1	1	1		
<i>Schizothorax plagiostomus</i> ⁴	> 50				1		
<i>Schizothorax progastus</i> ^{2, 3 and 4}	40-50		1	1	1		
09 Rare or Near threatened (R)		2	0	0	0	0	0
<i>Erethistoides ascita</i> ¹	< 10	1					
<i>Erethistoides cavatura</i> ¹	< 10	1					
10 Exotic		0	0	0	0	10	0
<i>Oreochromis niloticus</i> ⁵	20-30					1	
<i>Barbonymus gonionotus</i> ⁵	30-40					1	
<i>Cyprinus carpio</i> ⁵	40-50					1	
<i>Ctenopharyngodon idella</i> ⁵	> 50					1	
<i>Hypophthalmichthys molitrix</i> ⁵	> 50					1	
<i>Hypophthalmichthys nobilis</i> ⁵	> 50					1	
<i>Oncorhynchus mykiss</i> ⁵	> 50					1	

Conservation status and species	Size category (cm)	Endemic fishes ¹	Fishes for fishery ²	Game fishes under pressure ³	Native fishes propagated artificially ⁴	Fishes for present fish culture ⁵	Fishes for future fish culture ⁶
<i>Pangasianodon hypophthalmus</i> ⁵	> 50					1	
<i>Clarias gariepinus</i> ⁷	> 50					1	
Grand Total		17	11	29	10	12	22

(Source: Shrestha 2019^{1, 2 and 3}; Dhakal et al. 2022^{4, 5 and 6}; CFPCC 2019⁷)

In addition to the conservation status, selected fishes in Nepal are also distinguished by their traditional/cultural role and values such as those being preserved in temple pools (*Anguilla bengalensis bengalensis*, *Naziritor chelynooides*, *Neolissochilus hexagonolepis*, *Tor mosal*, *Tor putitora* and *Tor tor*) or propagated by Buddhist monks in the monasteries' ponds as sacred fish (*Channa orientalis*, *Schizothorax labiatus* and *Schizothorax macrophthalmus*) and used in ethnomedicine (*Channa orientalis* and *Channa punctata*) (Shrestha 2019).

Though the attention of fishers/sport fishers turns to fish which grow to larger size, in Europe and Asia mainly the small carps, while in North America minnows and shiners, in Africa and in South America the numerous small characids are those small indigenous species (SIS) which, being indispensable in the food chain (food web), are important part of the fish fauna of all natural waters. In the past neither the ecological nor the food value of SIS have always been merited by decision makers of the sector as they should be. Regarding the ecological value of SIS, these fishes, both keep balance by utilizing otherwise unexploited niches of the waters and serve as prey for predator fishes. The nutrition value of SIS both in the historical and modern diet calls for attention (Roy et al. 2003; Gupta and Rai 2014; Yadav and Rai 2014; Rai et al. 2018). In the past, and also at present SIS are widely consumed as relish or as finger food with beverages, which makes these fish well priced if their quality is good. In Nepal there are a total of 71 species which do not grow larger than 20 cm and 86 fish species which do not grow larger than 10 cm (Shrestha 2019). Most of these species belong to the family of Cyprinidae (Table 1). As the SIS are also self-recruiting species (SRS), their role in rice-fish culture and pond polyculture is considerable in the entire region. Out of the SIS there are a few small carps such as pothi (*Puntius sophore*), mara (*Amblyphrynogodon mola*), dedhuwa (*Esomus danrica*) and chela (*Chela cachius*) which have already been widely tested and found especially valuable as additional fishes in the seven/eight species carp polyculture not only in Nepal, but also throughout the neighboring regions where the fish fauna, the production and social conditions are similar to the Terai (Roy et al. 2003; Yadav and Rai 2014; Gupta and Rai 2014; WorldFish 2022). However, it is not only Nepal and the neighboring countries where SIS have distinct room in carp polyculture, but also in the pond culture throughout Eurasia, where the role of the numerous native and accidentally introduced SIS in pond culture is very similar to that one experienced in Nepal and the subcontinent; in nursery ponds not a single specimen of SIS (or any other species) should be allowed to enter, while the presence of these species is even advantageous in ponds where predatory species are added to and reared. In Eurasia such polycultures of table fish had been practiced since the introduction of modern, science-based pond culture of fishes. In addition to being prey, or harvested to eat, SIS from pond polyculture are often graded and sold alive as bait fish in countries worldwide, where recreation fishery of predatory species is popular. SIS relevancy is not clear.

Concerning introduction of fish species, Nepal followed the international trends driven by expected ecological and economic advantages. Out of the sixteen introduced species some of them were brought in for ornamental reasons or biological control of mosquitoes, but most of them a total of eleven were introduced to use in commercial and recreational fishery, as well as in fish culture. The first commercially important exotic species, the warmwater common carp, the coldwater rainbow trout, then the Chinese major carps were first introduced in the 1950's, late 1960's and early 1970's, respectively (FAO 1974). Due to initial failures the successful introduction of rainbow trout has started only in 1988 when a new batch of fish seed arrived from Japan (Gurung and Basnet 2003).

From the 1970's, especially for increasing the choices and range of cultured fish species the list of exotic fish species widened, which are marked as "fishes for present fish culture" in Table 1. According to the available information none of the introduced species became invasive in Nepal.

Fishery management



(Photo by Elek Woynarovich)



(Photo by Andras Woynarovich)

Woynarovich)

Figure 3: Small scale fishing with home-made equipment in the 1960's (left) and widely available nets today (right).

The two prime objectives of fishery management defined by FAO (1997) are the long-term conservation and the sustainable use of the resources (i.e., natural waters and fish fauna).

With national characteristics the fishery management of natural waters in Nepal has been shaped and developed similarly to the international trends:

until late 1950's and early 1960's fishing in the natural waters could be characterized as typically traditional, small-scale artisanal subsistence, when only the capital specimens, otherwise the surpluses of captured fish were sold.

In the 1960's and early 1970's, parallel to the increase of the population and construction of roads small-scale commercial fishing became dominant. By opening the country for tourism recreational fishing has also been introduced and promoted with focus on the native fishes such as Sahar or Mahseer (*Tor tor*, *Tor putitora*), Asala (*Schizothorax spp.*), Katle (*Neolissochilus hexagonolepis*), Rewa (*Barbus chagunio*), Kande (*Systomus sarana*), Gardi (*Labeo pangasia*), Junge (*Mystus spp.*), Bam and Chhuchhe Bam (local eels) (HMGN 1970).

As set by Aquatic Animal Protection Act (Nepal Law Commission 2024), today small-scale artisanal fishing both subsistence and commercial together with recreational fishing are the typical methods for catching fish which are proven being suitable and proportional to the country (FAO 1974; Shrestha 1999; Gurung 2003; FAO 2005; Gurung et al. 2020).

Due to the increased fishing pressure on the natural waters an overall fishery management development plan including systematic and fundamental fishery biological survey of fishes in all river systems was recommended by FAO in 1974. Later in the subsequent years when fish culture techniques and technologies including fish seed production have further developed the obstacles of conservation and enhancement were eliminated. Similarly, to international trends missing information on and weaknesses of conservation and enhancement of fishery in natural waters were identified, researched and science-based solutions were recommended to be included into national management policies for regulation-oriented and controlled activities of fishers related to fishing activities and gears. Policy recommendations also included internationally already tested fish population enhancement techniques such as restocking, as well as measurements (setting close seasons and close spawning grounds) for maintaining the adequate aquatic environment (FAO 1974; Shrestha 1999; Swar 2002; Shrestha 2002a; Gurung 2003; FAO 2005; Gurung et al. 2020; Dhakal 2022).

International experiences have proved that the actual results of the fishery in natural waters basically depends on continuous quantitatively and qualitatively adequate replacement of captured fish with the younger new generations. In order to ensure these different measures and techniques have been elaborated and extensively practiced in the inland fishery for centuries. These are among others: setting close seasons, establishment of fish sanctuaries (i.e., area closed for fishing), restriction on catch size and quantities of fish, providing license to fisher, prohibiting use of destructive fishing gears, as well as restocking of farm propagated fish seed. Enhancement of fishery by close seasons paired with establishment of areas closed for fishing is a very efficient measure to exploit and utilize the reproduction potentials of fish stocks in the natural waters.

Though the fisheries management in national parks in Nepal is complex, fish conservation and fishery enhancement in their waters by controlled stock management and established fish sanctuaries could be a feasible solution. This idea inspired by Bista and Karki (2022) should not face difficulties in the fishery utilization of the waters of the 15815 km² large national parks and 16750 km² large conservation areas. As the total area of national parks and conservation reserves is 32565 km². Here, which is about 22% of the country's total area, different all-aspects wise sustainable fishery practices could be modeled, researched/tested and extended on a large-scale (NTB 2024).

Setting close seasons for the main spawning period of the different species has been practiced for centuries worldwide. However, this does not always help because the spawning grounds are destroyed or/and the access of fish, migrating to these locations are blocked. By today a wide range of propagation techniques and technologies for many native fish species have been elaborated also in Nepal (Dhakal et al. 2022). Therefore, the negative effects of blocked or aggravated migration and the increased fishing pressure can be mitigated or even eliminated if culture-based fishery (CBF) is practiced. This type of fishery enhancement, i.e., the stocking of different age/size groups of target species according to the fish/ecological carrying capacity of both lentic and lotic water bodies is practiced successfully worldwide.

The ideal situation is that CBF is practiced together with close seasons and restrictions on catch size (MLS) and total allowed catches (TACs). As these are well known and even set by law, all conditions are given to perform efficient fishery management of natural waters in Nepal.

FISH CULTURE

Modern coldwater and warmwater fish culture in Nepal started parallel in the 1950's. The first step included finding suitable waters for both cold and warmwater fish culture. Some of the sacred coldwater springs' tanks, warming-up temple pools and village ponds were identified and started to be used as first locations for fish culture. Their size ranged between 100 and 5000 m² (FAO 1969).

By early 1960's there were operational fishery stations in Godawari, Parwanipur, Janakpur, Tarahara, Pokhara and Bhairahawa, while Rampur (Rapti valley) and Jhapa (East Nepal) fishery stations were under projection (FAO 1965; Yamamoto 1966 and 1967). In addition, there were a few private fish farms with a total area of not more than a few hectares (FAO 1969).

The introduced coldwater rainbow trout and warmwater common carp together with the native Indian major carps were the first species to culture. At the beginning seeds of these species were imported. Later, in the 1960's and 1970's when government fish farms were built for both cold and warmwater species their artificial propagation techniques were adapted, Nepal became self-sufficient in fish seed supply of that time cultured species. In the same period when easy and reliable fish seed supply became widespread table fish production also developed rapidly.

Because of the diverse environmental conditions and fishery resources, by today a complete set of cold and warmwater fish production technologies are developed and practiced in Nepal.

Fish culture systems practiced

International trends in the development and use of three fish culture systems are based on century long experiences. These are; (1) culture-base fishery (CBF) where growth of fish is exclusively based on natural food, (2) pond culture, which is based on the combination of natural food and supplementary feeds can be extensive, semi-intensive and intensive, while (3) the intensive culture systems (such as tank and cage culture) are based on nutritionally complete industrial feeds. Practically the three basic systems developed parallel, but it was only the invention and extensive introduction/use of nutritionally complete industrial fish feeds in the 1970's when intensive culture systems of both coldwater, warmwater and tropical fish species became technically and financially feasible.

Depending on the physical, chemical and biological qualities of available water, all economically and ecologically important coldwater, warmwater and tropical fish species can be widely cultured. Out of coldwater stenothermal species the introduced rainbow trout is produced in intensive culture systems. These may range from coldwater ponds, pools, raceways and different tanks to floating cages set in suitable water bodies. Regarding the valuable native coldwater species such as snow trout (*Schizothorax* spp.), their successful controlled propagation was reported by Rai and his colleagues already in 2002. That time the lack of suitable feeds in general and appropriate feeding techniques for larvae rearing in particular were identified as the main obstacles of their rearing on (Rai et al. 2002).

Warmwater eurythermal fish species among others common carp, Chinese major carps, and Sahar are typically reared in pond culture of different intensity. It is done even if these species can also be

cultured in intensive culture systems. Out of carps the two filtering species the silver carp and the bighead carp became part of an exceptional initiative in cages in lakes and reservoirs presented in Chapter entitled “Table fish production”. The tropical stenothermal fish species such as tilapia, African catfish and pangasius are produced both as part of pond polyculture and in intensive culture systems. Regarding the potential native fish species such as Sahar (*Tor putitora*), Asala (*Schizothorax* spp.), Gardi (*Bangana dero*), Magur (*Clarias batrachus*), and Singhi (*Heteropneustes fossilis*), these and similar fishes can be used as additional fish species in pond polyculture.

Fish seed production

In the last century one of the main reasons for international trends in introducing trout and common carp was that their propagation and fry rearing technologies have already been known. Hence their production could be fast adapted and started. Considering the breakthrough in the artificial propagation of common carp, Chinese and Indian major carps in the 1970's the elaboration of the propagation techniques and fingerling production of all important native and indigenous species were recommended even initiated with preliminary investigation on their reproduction biology and habits (FAO 1974; Woynarovich 1975).

In the subsequent three decades the propagation of the commercially important native fish species listed in Table 1 was practically solved hence the domestication of these species could start (Shrestha 2002b; Rai et al. 2002; Swar 2002; Gurung et al. 2002; Joshi et al. 2002; Bista et al. 2002; Gurung 2003).

By today fish seed of different growth stages are produced in 343 fish propagation and fish-seed production farms. Accordingly, the 5 Fisheries Research Centers, the 7 Fisheries Development Centers, the hatcheries of AFU, IAAS-TU, the 99 private hatcheries and the 232 nurseries which produce fish larvae and supply fish seed of different species and age groups (FAO 2005; Gautam and Sapkota 2023).

Table fish production

From scratch start in the 1950's fish production in farms has grown to 87385 mt by 2022 (Table 2). It is four times more than the quantity of fish captured in natural waters (FAO 2024). These results demonstrate that impressive development, which started with the stocking of a few pools in the Kathmandu Valley (Taft 1955). The next stage of fish culture development for consumption can be dated to the 1960's, when the use of temple and village ponds for controlled fish production was initiated. Parallel to the exploitation of widely available temple and village ponds with CBF or pond culture of different intensities, construction of government pond fish farms both for fish seed and table fish supply started already in the 1960's and early 1970's that continued during the subsequent decades. During the early periods fish farm at Bhandara (at present Fisheries Development Center, Bhandara), the Central Hatchery at Balaju, Breeding and Distribution Centre at Tarahara, Fish farm at Janakpur, as well as Trout hatchery cum fish farm both in Godawari and Trishuli were established/constructed (FAO 1974).

Table 2: Fish production from culture by species in 2022

Production in fish farms	Mrigal carp	Common carp	Grass carp	Bighead carp	Rohu	Silver carp	Pangasius	Catla	Nile tilapia	Rainbow trout	Total
Quantity (mt)	21915	21521	10346	9050	8854	8763	2309	2150	1 850	627	87385
Prop. (%)	25	25	12	10	10	10	3	2	2	1	100

(Source: FAO 2024)

This development period was in line with international trends which focused mainly on large-scale pond fish culture. Though this continued further in the past decades the role of small-scale pond culture was identified among others to fight against poverty and unemployment in the region. For this reason, construction of household ponds was supported throughout the Terai. Parallel intensive carp pond polyculture technologies of at least seven, but usually more, even nine or ten different species including increased number of periphyton feeders and carp-SIS were introduced. These technologies developed and disseminated especially for household ponds between the 1980's and 2000's allowed to produce high yields (4-5 t/ha/season) only with traditional materials such as manure and supplementary feeds found in the households (Bista et al. 2002; Woynarovich 2004; Yadav and Rai 2014; Rai et al. 2018; WorldFish 2022).

By today the total area of pond fish farms is around 14745 ha (No. of ponds: 49862). Out of these the total area of pond fish farms in the mountain, hill and Terai regions are about 49 ha (No. of ponds: 670), 1453 ha (No. of ponds: 8874) and 12635 ha (No. of ponds: 40318), respectively (Gautam and Sapkota 2023).

In addition to pond culture, many of the warmwater fish species which accept artificial feeds can be technically produced in intensive culture systems using small earthen ponds, concrete tanks or cages placed in natural waters, reservoirs or ponds where fish are fed with reliable, nutritionally complete feeds. The exceptional example of Nepal is the use of cages in lakes, reservoirs for growing plankton filtering fish species. As Swar and Pradhan (1992) summarized cage culture of fish in Nepal started in 1972. After the first trials in Lake Phewa this was extended into all three lakes in Pokhara valley. Uniquely the major species are the two plankton filtering silver and bighead carps. These are grown in floating cages without supplemental feeding. Fish stocking density varied between 6 and 10 fish/m³ as per actual trophic state of the lakes. Mortality was as low



(Photo by Elek Woynarovich)

Figure 4: One of the first harvest of carp polyculture in early 1970's (above) and table fish from a household and the sale of live fish in the 2010's (below).



(Photos by Andras Woynarovich)

as 6% and annual production remained between 3.4 and 5.0 kg/m³. Swar and Pradhan concluded that a five-cage system proved to be a considerable additional yearly income. In this regard Shrestha et al. (2002) recommended that the total cage culture area on these lakes should not exceed 1-2% of the total water area. In Nepal the total volume of cages was around 71205 m³ and their total production was 370 mt fish in 2022/23 (Gautam and Sapkota 2023).

Integration of growing rice with fish culture and pond culture with animal husbandry are the most widely practiced techniques in Asia. Therefore, already in early 1960's integrated rice cum fish production was successfully tested. In late 1960's integrated duck cum fish culture was introduced. Out of these two integrations, rice cum fish culture have not gained popularity (FAO 2005).

Table fish production of coldwater fish species especially of rainbow trout is widely done in about 98 small and medium size trout farms (CFPCC 2019). Their estimated total production space is around 60800 m². In 2023 its reported production was 1007 tons, about 0.9% of total fish culture production in 2022/23 (Gautam and Sapkota 2023).

Technical education and extension in fishery and aquaculture

Technical education and extension in fishery and aquaculture in Nepal also followed the international trends. Accordingly, by today, both technical education and extension services are well established. Out of the different level of technical education on fishery and aquaculture, higher and vocational educations (technical trainings) are the two determining opportunities to establish reliable theoretical and practical knowledge. Higher education in the form of B.Sc. Fisheries, M.Sc. Fisheries and Ph.D. degrees are offered in the Agriculture and Forestry University (AFU) and M.Sc. Aquaculture and M.Sc. Zoology (Fish Biology and Aquaculture) in the Tribhuvan University (TU). At present around 20 students graduate yearly on such degrees from AFU.

The first efforts to establish professional support of extensionists and provide training for fish farmers in Nepal started early 1970's, when the fish culture manual entitled '*Elementary Guide to Fish Culture in Nepal*' was written by Elek Woynárovich. In 1973 one of the first handouts entitled 'Fish Culture and Fish Culture Extension' was translated into Nepali (FAO 1974).

In the 1960's there were only a few fish farmers and the number of people were also less than in the 2000's when about 140000 household and over 500000 individuals were estimated to be engaged in fishery, aquaculture and associated activities in early 2000's. It seems that since these statistical data published by FAO in 2005 has not changed considerably.

The importance of education and training in the fisheries sector was recognized during the 1980's when aquaculture development activities expanded remarkably in the country (FAO 2005). As the



Figure 5: Pond side consultations cum sampling of fish are important elements of extension and field training.



(Photos by Andras Woynarovich)

aquaculture industry rapidly grew in Nepal, it was realized that specialized technical manpower is indispensable to the further sustainable development of the fisheries (both fishery and fish culture). Therefore, B.Sc. Fisheries program started in AFU from 2014. Since fisheries trainings have been provided to farmers of different scales (Gurung et al. 2013). In the extension activities not only GOs, NGOs and universities participate, but also international organizations.

Previously out of GOs, the Directorate of Fisheries Development (DoFD) under the Department of Agriculture, Ministry of Agriculture and Cooperatives was responsible for fisheries and aquaculture extension-related policy and implementation. Now, after federal government established, it is the Central Fisheries Promotion and Conservation Centre (CFPCC). It also coordinates with national and international institutions with focus on fisheries extension. The centre performs its work through the following major institutions: (1) Fisheries Technology Validation and Human Resources Development Center, (2) Natural water Resources Promotion and Conservation Center and (3) Fisheries Pure Line Breed Conservation and Promotion Resource Center. At provincial levels, there are Fisheries Development Centers situated in seven different provinces under the Provincial Directorate of Livestock and Fisheries Development. There are Agriculture Development Bank and farmers' cooperatives for credit facilities and services (Gurung et al. 2013).

RECOMMENDATIONS

Though the implementation of international trends in inland fishery and fish culture of Nepal was definitely very successful, still there are details, which should be considered by concerned scientists, practical professionals, policymakers and decision makers of the sector. These are as follows:

Research work for advanced fishery enhancement in rivers: Well-known fish fauna and its consisting species are the preconditions of successful fishery management of natural waters. Therefore, extensive field surveys of fish fauna, endangered fish species and ecological conditions should continue to keep pace with the processes generated by climate-change and human activities. Consequently, further research and description of the physical, chemical and biological (including fish fauna) properties and ecological characteristics of rivers as per their long profile sections should continue, on a nationally coordinated manner. These will allow that fish fauna and their species, which occupies the different river sections to be observed, considered, discussed and managed on a holistic manner.

Piloting fishery management techniques under controlled conditions: Reviewing and analyzing the fishery resources in the national parks where fishery can be better controlled than elsewhere, will allow the elaboration and test of technical and human aspects of fishery management on natural waters. In this process members of the local (fishing) communities could easily be involved not only as fishers who participate in sampling, but also as fish warden cum angling guide to tourists. Piloting fishery management approach should also include considerations on the development of a stocking/restocking schemes of natural water when fishers and fishing communities would be trained and supported to produce fish-seed of commercially and/or ecologically important native fishes for restocking the natural waters. This will ensure paid involvement through active participation in CBF. This will promote not only fishing results, but also the domestication and increased production of commercially and ecologically important native fish species. For the effective implementation of management practices, skilled fisheries technical manpower is needed which national parks lack at present.

Promotion of household fish nurseries: Training fishers and small-scale fish farmers for rearing advanced fry and fingerling from widely available relatively cheap fish larvae produced in

government and private hatcheries will positively affect and improve fish seed markets. Because such production is short, fish nurseries will ensure fast return and higher income than rearing table fish. Moreover, growing larger fingerlings and stocking them increases fish production.

Trainings to fish farmers: Role of participatory training on pond and fish rearing devices construction and maintenance, water quality and disease management, as well as on the wide options of table fish production, including intensive culture systems and clearly understood nursery operations are the guaranty of the success. Therefore, capacity building should go on by strengthening fish farmers in physical and financial planning and evaluation of production, reviewing production and market conditions in order to decide accordingly both on the intensification and diversification of their actual and future fish production.

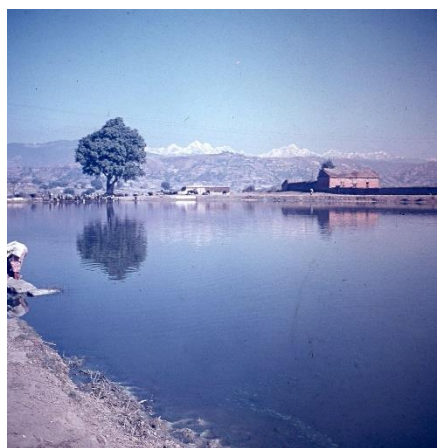
Higher education: Higher education on inland fisheries and aquaculture plays vital role in producing skilled manpower for research and extension. There should be physical and soft skill capacity enhancement of the related departments and programs in the AFU and TU. With the development of fisheries and aquaculture, there is a need of separate fisheries college or fisheries faculty to run the fisheries education in the country. This recommendation is further supported by the fact that complex fishery management of natural waters is outstandingly focused and the role of fish culture production in food security is increasingly important.

Collaboration, cooperation and coordination among education, research and extension institutions, as well as among the three levels of government for fishery and aquaculture would be an additional guarantee for further sustainable development of the sector.

CONCLUSIONS

The present review aimed to compile a concise inventory of the key technical aspects how international trends in fishery and fish culture were implemented in Nepal. Regarding worldwide introductions of fish species there are basically new trends, according which domestication of native species are preferred to the introduction of exotic/alien fishes. The new trends have been well understood, and similarly to many other countries these were also observed and followed in Nepal. Accordingly, propagation techniques and technologies of native fish species were elaborated and the domestication of fish species found suitable for fish culture started.

It is important to conclude, that the development of fishery and fish culture avoided significant pitfalls, those experienced elsewhere. This in its own, is a very considerable accomplishment in the development of fishery and fish culture in Nepal. However, in case of an even more consistent, traditional-fish-folk-friendly enforcement of fisheries controlling acts and regulations, the present state of the sector can be one of the good examples of the traditions and exceptional fishery resources professionally matching sector, which is prospering within a magnificent natural and cultural environment, that Nepal offers.



(Photos by Elek Woynarovich)

Figure 6: A village pond in late 1960's.

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REFERENCES

- Bhuju, U.R., Khadka, M., Neupane, P.K., & Adhikari, R. (2010). A map based inventory of lakes in Nepal. *Nepal Journal of Science and Technology*, 11: 173-180. <https://doi.org/10.3126/njst.v11i0.4141>.
- Bista, J., Pradhan B.R.; Rai A.K.; Shrestha R.K., & Gurung T.B. (2002). Nutrition, feed and feeding of gold mahseer (*Tor putitora*) for domestication and production in Nepal. In: T. Petr, & D.B. Swar (Eds.), *Cold water fisheries in the trans-Himalayan countries*. FAO Fisheries Technical Paper. No. 431 Rome, FAO. 107-118.
- Bista, S., & Karki, T. (2022). Legal instruments in fisheries sector of Nepal. *Reviews in Food and Agriculture*, 3(2): 62-66. <https://doi.org/10.26480/rfna.02.2022.62.66>.
- CFPCC (2019). Annual Progress Book 2075/76. Central Fisheries Promotion and Conservation Center. Ministry of Agriculture and Livestock Development. p. 78.
- Dhakal, A., Pandey, M., Kayastha, P., Suwal, G., & Suwal, B. (2022). An overview of status and development trend of aquaculture and fisheries in Nepal. *Advances in Agriculture*, 2022(1): 16 pp. <https://doi.org/10.1155/2022/4206401>.
- FAO. (1965). Report on development prospects of the fisheries of Nepal. Based on the work of John L. Dibbs. Rep. FAO/EPTA (No. 2105): 23 p.
- FAO. (1969). Report to the Government of Nepal on fish culture development. Based on the work of K.K. Zwilling, FAO/TA Fish Culturist. Rep. FAO/UNDP(TA), 2754, FAO, Rome, 14 p.
- FAO. (1974). Report to the Government of Nepal on inland fishery biology. Based on the work of Elek Woynarovich. Rep. FAO/UNDP(TA), (3287): 24 p.
- FAO. (1997). Inland fisheries. FAO Technical Guidelines for Responsible Fisheries. No. 6. Rome, FAO. 36 p.
- FAO. (2005). National aquaculture sector overview: Nepal. FAO Fisheries & Aquaculture Department, National Aquaculture Sector Overview: Nepal. www.fao.org.
- FAO. (2024). FishStat: Global production by production source 1950-2022. In: FishStatJ. Accessed on 29 March 2024 from www.fao.org/fishery/en/statistics/software/fishstatj. License: CC-BY-4.0.
- Gautam, S., & Sapkota, P. (2023). Status and development trend of aquaculture and fisheries in Nepal. *Nepalese Journal of Aquaculture and Fisheries*, 10, 1-13. <https://doi.org/10.3126/njaf.v10i1.78786>.
- Gubhaju S.R. (2002). Impact of damming on the aquatic fauna in Nepalese rivers. p. 129-148. In: T. Petr, & D.B. Swar (Eds.), *Cold water fisheries in the trans-Himalayan countries*. FAO Fisheries Technical Paper. No. 431 Rome, FAO.
- Gupta, M.C., & Rai, S. (2014). Effect of dedhuwa (*Esomus danricus*), mara (*Amblypharyngodon mola*) and pothi (*Puntius sophore*) on carp-prawn production in Chitwan, Nepal. *Nepalese Journal of Aquaculture and Fisheries*, 1, 73-84.
- Gurung, T.B. (2003). Fisheries and aquaculture activities in Nepal. *Aquaculture Asia*, VIII(1), 14-19.
- Gurung, T.B. (2016). Role of inland fishery and aquaculture for food and nutrition security in Nepal. *Agriculture and Food Security*, 5: 18-26. <https://doi.org/10.1186/s40066-016-0063-7>.
- Gurung, T.B., & Basnet, S.R. (2003). Introduction of rainbow trout (*Oncorhynchus mykiss*) in Nepal: Constraints and prospects. *Aquaculture Asia*, VIII(4): 16-18.
- Gurung, T.B., Rai, A.K., Joshi, P.L., Nepal, A., Baidya, A., & Bista, J. (2002). Breeding of pond reared golden mahseer (*Tor putitora*) in Pokhara, Nepal. p. 147-160. In: T. Petr, & D.B.

- Swar (Eds.). Cold water fisheries in the trans-Himalayan countries. FAO Fisheries Technical Paper. No. 431 Rome, FAO.
- Gurung, T.B., Rijal, P.K., Gurung, K., Ranjan, R., Rayamajhi, A., Jha, S.K., Timalisina, P., & Nepal, A.P. (2020). Unlocking legal and policy frameworks for small-scale fisheries in Nepal. In: Kerezi V., Nakamura J., El Halimi M., & Chuenpagdee R. (Eds.), *Unlocking Legal and Policy Frameworks for Small-Scale Fisheries: Global Illustrations*. TBTI Global Publication.
- Gurung, T.B., Upadhyaya, K.K., Pradhan, G.B.N., & Shrestha, M.K. (2013). Fisheries and aquaculture policy for education, research and extension in Nepal. p. 6-9. In: Shrestha, M.K.; Pant, J. (eds.) *Small-scale aquaculture for rural livelihoods: Proceeding of the National Symposium on Small-scale Aquaculture for Increasing Resilience of Rural Livelihoods in Nepal*. Institute of Agriculture and Animal Science, Tribhuvan University, Rampur, Chitwan, Nepal and the WorldFish Center. Penang, Malaysia
- Joshi, P.L., Gurung T.B., Basnyat, S.R., & Nepal A.P. (2002). Domestication of wild golden mahseer (*Tor putitora*) and hatchery operation. p. 173-178. In: T. Petr, & D.B. Swar (Eds.), *Cold water fisheries in the trans-Himalayan countries*. FAO Fisheries Technical Paper. No. 431 Rome, FAO.
- Labh, S.N., Kayastha, B.L., Shakya, S.R., Kushwaha, M.P., Vaidya, S.V., & Dhital, K.S. (2017). Present status and future perspectives of freshwater fisheries in Nepal: A short review. *International Journal of Fisheries and Aquatic Studies*, 3, 95-97.
- Nepal Law Commission. (2024). Aquatic Animal Protection Act, 2017. Available at <https://lawcommission.gov.np/category/1786/>.
- NTB. (2024). National parks of Nepal. Nepal Tourist Board. Available at <https://ntb.gov.np/national-parks-of-nepal>.
- Rai, A.K., Pradhan, B.R., Basnet, S.R., & Swar, D.B. (2002). Present status of snow trout in Nepal. p. 213-220. In: T. Petr, & D.B. Swar (Eds.), *Cold water fisheries in the trans-Himalayan countries*. FAO Fisheries Technical Paper. No. 431 Rome, FAO.
- Rai, S., Gharti, K., Shrestha, M., Ranjan R., Diana, J., & Egna, H. (2018). Potential substrates for periphyton enhancement in Carp-SIS polyculture. *Out Nature*, 16(1), 8-16. <https://doi.org/10.3126/on.v16i1.21559>.
- Roy, N. C., Kohinoor, A.H.M., Wahab, M.A., & Thilsted, S.H. (2003). Evaluation of performance of Carp-SIS polyculture technology in the rural farmers' pond. *Asian Fisheries Science*, 15(2): 43-52. <https://doi.org/10.33997/j.afs.2002.15.1.005>.
- Shrestha, M.K., Batajoo, R.K., & Karki, G.B. (2002). Prospects of fisheries enhancement and aquaculture in lakes and reservoirs of Nepal. p. 289-296. In: T. Petr, & D.B. Swar (Eds.), *Cold water fisheries in the trans-Himalayan countries*. FAO Fisheries Technical Paper. No. 431 Rome, FAO.
- Shrestha, T.K. (2002a). Cold water Fisheries Development in Nepal. p. 47-58. In: T. Petr, & D.B. Swar (Eds.), *Cold water fisheries in the trans-Himalayan countries*. FAO Fisheries Technical Paper. No. 431 Rome, FAO.
- Shrestha, T.K. (2002b). Ranching mahseer (*Tor tor* and *Tor putitora*) in the running waters of Nepal. p. 297-300. In: T. Petr, & D.B. Swar (Eds.), *Cold water fisheries in the trans-Himalayan countries*. FAO Fisheries Technical Paper. No. 431 Rome, FAO.
- Shrestha, T.K. (2019). *Ichthyology of Nepal – A study of fishes of the Himalayan waters* (Second revised edition). B.J. Shrestha, Kathmandu, Nepal, ISBN: 978-9937-0-5138-5.
- Swar, D.B. (2002). The status of coldwater fish and fisheries in Nepal and prospects of their utilization for poverty reduction. p. 79-98. In: T. Petr, & D.B. Swar (Eds.), *Cold water fisheries in the trans-Himalayan countries*. FAO Fisheries Technical Paper. No. 431 Rome, FAO.

- Swar, D.B., & Pradhan, B.R. (1992). Cage fish culture in the lakes of Pokhara valley, Nepal, and its impact on local fishers. *Asian Fisheries Science*, 5, 1-13. <https://doi.org/10.33997/j.afs.1992.5.1.001>.
- Taft, A.C. (1955). A Survey of the fishery of Nepal, both present and potential. Report by United States Overseas Mission (USOM), for Nepal- American Agriculture Cooperative Services, Kathmandu, Nepal, p. 34.
- Thapa, N.B., & Thapa, D.P. (1969). *Geography of Nepal (Physical, Economic & Regional)*. Orient Longmans, Bombay, p. 205.
- WorldFish. (2022). Taking Nutrition-Sensitive Carp-SIS Polyculture Technology to Scale. Fact Sheet: 2022-26. Available at <https://hdl.handle.net/20.500.12348/5302>.
- Woynárovich, A. (2004). Project Completion Report – Mymensingh Aquaculture Extension Component, Consolidation Phase (01/07/2000 – 31/12/2003). Danida, Ref. No. 104.Bang. 805 – 12, Mymensingh, Bangladesh.
- Woynarovich, E. (1975). Elementary guide to fish culture in Nepal. FAO, Rome, p. 131.
- Yadav, S.K., & Rai, S. (2014). Production potential of carp-SIS-prawn polyculture in Chitwan, Nepal. *Nepalese Journal of Aquaculture and Fisheries*, 1, 59-72.
- Yamamoto, T. (1966). Travel Report on a Visit to Nepal. Doc. No. FID/66/R4, FAO Regional Office, Bangkok, 7 p.
- Yamamoto T. (1967). Travel Report on Visit to Nepal – Inland fisheries Development Problems. Doc. No. FID/67/R11, FAO Regional Office, Bangkok, 5 p.



GROWTH PERFORMANCE OF NILE TILAPIA (*Oreochromis niloticus*) IN MONOCULTURE AND POLYCULTURE SYSTEMS WITH CARPS AND SAHAR (*Tor putitora*) UNDER ON-FARM CONDITIONS

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ABSTRACT

Carp polyculture is the dominant aquaculture system in Nepal; however, its productivity remains relatively low, and diversification with improved culture systems is needed. A 150-day on-farm experiment was conducted in Chitwan, Nepal using 12 earthen ponds (200 m² each) to evaluate the growth performance of Nile tilapia (*Oreochromis niloticus*) under monoculture and polyculture systems. The experiment was arranged in a completely randomized design with four treatments and three replications of each: a) Existing carp polyculture (10,000/ha) + mixed-sex tilapia (3,000/ha) + sahar (1,000/ha) (T₁); b) Existing carp polyculture + monosex tilapia (3,000/ha) (T₂); c) Monosex tilapia at 10,000/ha with fertilization only (T₃); and d) Monosex tilapia at 20,000/ha with fertilization and feeding (T₄). Combined net fish yield was significantly lower in T₃ (0.71±0.02 t/ha/crop) compared to other treatments (p<0.05), whereas no significant differences were observed among T₁, T₂, and T₄ (2.49-2.57 t/ha/crop). Monosex tilapia in T₄ exhibited significantly higher harvest weight, daily weight gain, and yields than in T₃. Gross profit margin was lowest in T₃, whereas T₁, T₂, and T₄ showed comparable and higher economic returns. These results indicate that carp-tilapia-sahar polyculture, carp-monosex tilapia polyculture, and fed monosex tilapia monoculture are economically viable and productive alternatives to traditional carp polyculture system, offering improved pond productivity and species diversification in Nepal.

Keywords: Nile tilapia, carps, sahar, monoculture, polyculture

INTRODUCTION

Semi-intensive carp polyculture is a well-established aquaculture system in Nepal. This system typically utilizes fertilized ponds supplemented with feed and commonly includes silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Aristichthys nobilis*), common carp (*Cyprinus carpio*), grass carp (*Ctenopharyngodon idella*), rohu (*Labeo rohita*), and mrigal (*Cirrhinus mrigala*) (Shrestha et al. 2022; Pandit et al. 2023). These six species are recommended at specific ratios with a combined stocking density of 10,000-12,000 fish/ha. However, fingerlings of all recommended species are rarely available at the required time for stocking, and in practice, farmers typically culture only four to six species. As a result, the average annual pond yield under this system remains relatively low, at approximately 5.5 t/ha/yr (MoALD 2023).

The inclusion of additional compatible and proven species, such as Nile tilapia (*Oreochromis niloticus*) and sahar or mahseer (*Tor putitora*), at increased stocking densities within existing carp polyculture systems has been shown to substantially enhance productivity. Previous studies reported yield increases of up to 57% and net return improvements of 61% without additional inputs (Shrestha et al. 2012; Shrestha et al. 2018; Pandit et al. 2023). Nile tilapia primarily consume plankton, thereby contributing to improved pond water quality and reduced nutrient loads in harvest effluents. Enhanced water quality, increased economic returns, and higher fish production without

additional inputs collectively improve the environmental and economic sustainability of aquaculture systems. Sahar is a native and endangered fish species (IUCN 2017), and its integration into carp polyculture systems can contribute to conservation efforts, more efficient utilization of pond resources, and control of excessive tilapia recruitment in carp ponds (Shrestha et al. 2011; Pandit et al. 2023).

In a previous experiment conducted by the authors, the incorporation of tilapia into carp polyculture resulted in significant increases in yield (29%) and profit margin (81%) when both tilapia and sahar were included (Shrestha et al. 2018). Despite these improvements, overall production remained relatively low at approximately 4 t/ha/yr. This level of production is considerably lower than that achieved in monosex tilapia culture systems in Thailand, where annual yields of approximately 5 t/ha using fertilizer alone and up to 20 t/ha in fed ponds have been reported (Diana 2012). These findings suggest that monoculture of tilapia could potentially outperform carp-based polyculture systems in Nepal in terms of total production and economic returns.

However, production results from Thailand cannot be directly extrapolated to Nepal due to differences in climate, particularly Nepal's cooler and more seasonal conditions. Therefore, this study aimed to evaluate monoculture of Nile tilapia and its integration into polyculture systems under Nepalese on-farm conditions to identify optimal strategies for incorporating tilapia into the national aquaculture sector. Given the endangered status of sahar, successful pond-based rearing could reduce fishing pressure on wild populations and potentially support stock enhancement programs, thereby contributing to the long-term sustainability of aquaculture in Nepal (Pandit et al. 2018).

The specific objectives of this study were to: (i) evaluate the performance of a carp-tilapia-sahar polyculture system and a monosex tilapia monoculture system under farmer-managed conditions; (ii) assess the culture potential of sahar and monosex tilapia for farmers; and (iii) develop partial enterprise budgets comparing production costs and fish values among the different culture treatments.

MATERIALS AND METHODS

The experiment was conducted at the Center for Aquaculture-Agriculture Research and Production (CAARP; a private farm), Kathar, Chitwan in twelve earthen ponds of 200 m² for 150 days (17 July to 15 December 2017) to verify the culture potential of sahar and tilapia to farmers. The experiment was conducted in a completely randomized design with four treatments in triplicate: a) Existing carp polyculture (10,000/ha) + mixed-sex tilapia (3,000/ha) + sahar (1,000/ha) (T₁); b) Existing carp polyculture and monosex tilapia at 3,000/ha (T₂); c) Monosex tilapia at 10,000/ha with fertilization only (T₃); and d) Monosex tilapia at 20,000/ha with fertilization and feeding (T₄). Silver carp, bighead carp, common carp, grass carp, rohu and mrigal of mean stocking size 44.2 and 45.3, 3.0 and 3.0, 9.9 and 9.7, 3.0 and 3.0, 29.8 and 32.9 g, and 17.33 and 17.6 g, respectively were stocked in six ponds of T₁ and T₂ at the ratio of 3.5:1:2.5:0.5:1.5:1. Mixed-sex Nile tilapia of 3.5 g and sahar of 7.0 g size were added in T₁. Similarly, the stocking size of all-male tilapia in T₂, T₃, and T₄ were 6.5, 6.5, and 3.2 g, respectively. All experimental ponds were completely drained and treated with hydrated lime (Ca(OH)₂) at the rate of 450 kg/ha. The ponds were sun dried for 2-3 days then filled with canal water. Ponds were then fertilized at 4 kg N and 1 kg P /m²/day with di-ammonium phosphate (DAP) (18% N and 46% P₂O₅) and urea (46% N). Fingerlings were stocked one week after pond fertilization. Subsequent fertilizations were done on weekly basis.

Feeding was done with commercial pellet feed (24% CP; Machapuchhre Feed Industry, Kapilvastu, Nepal) at 2% of total carp biomass per day. The proximate composition of feed was 90.0% dry matter, 26.6% crude protein, 8.6% crude fiber, 2.4% ether extract and 5.4% total ash. Feeding was done once in the morning between 09:00-10:00 a.m. The quantity of feed was adjusted monthly based on fish sampling. Fertilization with DAP and Urea was done fortnightly in all treatments. Sampling of fish was done monthly from each pond starting 30 days after stocking. During sampling about 10% of the stocked population of each species was weighed to calculate feed quantity for next month, assuming 100% survival. For final harvest, all ponds were drained by pumping and all fish were harvested and weighed.

Weekly and biweekly measurements of water quality parameters were conducted at 06:00-08:00 a.m. Water temperature, dissolved oxygen (DO), pH, and Secchi disk depth were measured in situ weekly using a DO meter (Lutron DO-5519), pH meter (Lutron pH-222) and Secchi disk, respectively. Water samples were collected biweekly from each pond using a plastic column sampler and analyzed for total alkalinity, total ammonium nitrogen (TAN), soluble reactive phosphorous (SRP), and chlorophyll a (APHA 1985). Proximate analysis of feed was done using methods provided in AOAC (1980).

Simple economic analysis was done to determine economic returns from each treatment (Shang 1990). The economic analysis was mainly based on farm gate price for harvested fish and current local market prices for all other inputs in Nepal. Prices for common carp, silver carp, bighead carp, grass carp, rohu, and mrigal fingerlings were 5, 10, 1, 2, 10, and 5 NRs/piece, respectively. Prices for sahar, mixed-sex tilapia, and monosex tilapia fingerlings were 5, 1, and 2 NRs/piece, respectively. Prices for DAP, urea and feed was 50, 22 and 20 NRs/kg, respectively. One US\$ is equivalent to NRs. 105.00.

The data were analyzed by one-way ANOVA using SPSS (V 16.0). For significant differences in growth parameters among different treatments, LSD was used to compare the means. For testing different growth and production parameters of carps, a T-test was used. For all analysis alpha was set at 0.05.

RESULTS

The gross fish yield and net fish yield in monosex tilapia without feed were significantly lower than monosex tilapia with feed and carp treatments (Table 1). The production of all carps was not significantly different between T_1 and T_2 ($p>0.05$). The production of tilapia in T_4 was significantly higher than T_3 ($p<0.05$). The combined extrapolated GFY of all species excluding and including tilapia recruits was significantly lower in T_3 than other treatments ($p<0.05$). Similarly, the combined extrapolated NFY of all species excluding tilapia recruits was significantly lower in T_3 than other treatments ($p<0.05$). The apparent food conversion ratio (AFCR) was significantly lower in T_4 compared to T_1 and T_2 without any significant differences between T_1 and T_2 (Table 1).

Table 1: Production parameters (mean $\pm$ SE) of different treatments

Parameters	Treatments			
	T ₁	T ₂	T ₃	T ₄
Extrapolated GFY (t/ha/crop)				
Carp	2.35 $\pm$ 0.25 ^a	2.25 $\pm$ 0.02 ^a	-	-
Tilapia	0.34 $\pm$ 0.07 ^a	0.60 $\pm$ 0.14 ^b	0.78 $\pm$ 0.23 ^b	2.60 $\pm$ 0.06 ^c
Sahar	0.06 $\pm$ 0.00	-	-	-
Combined excluding tilapia recruits	2.75 $\pm$ 0.24 ^a	2.85 $\pm$ 0.37 ^a	0.78 $\pm$ 0.3 ^b	2.60 $\pm$ 0.06 ^a
Combined including tilapia recruits	2.81 $\pm$ 0.25 ^a	2.85 $\pm$ 0.37 ^a	0.78 $\pm$ 0.03 ^b	2.60 $\pm$ 0.06 ^a
Extrapolated NFY (t/ha/crop) excluding tilapia recruits	2.49 $\pm$ 0.24 ^a	2.57 $\pm$ 0.36 ^a	0.71 $\pm$ 0.02 ^b	2.54 $\pm$ 0.06 ^a
FCR	2.23 $\pm$ 0.20 ^b	2.24 $\pm$ 0.10 ^b	0.00	1.60 $\pm$ 0.13 ^a

Mean values in a row with the same superscript are not significantly different ($\alpha = 0.05$).

There were no significant differences in mean harvest weight, total harvest weight, mean daily weight gain (DWG), survival rate, extrapolated GFY, and extrapolated NFY of different carp species among treatments (Table 2). However, mean harvest size, daily weight gain, GFY and NFY of monosex Nile tilapia in T₄ were significantly higher than in T₃ ($p < 0.05$).

Table 2: Growth and production parameters (mean $\pm$ SE) of each species in different treatments. Data based on a 200 m² pond for 150 days culture period

Parameter	Treatment			
	T ₁	T ₂	T ₃	T ₄
Common Carp				
Mean stocking weight (g)	9.9 $\pm$ 1.12 ^a	9.7 $\pm$ 0.37 ^a	-	-
Total stocking weight (kg)	0.50 $\pm$ 0.06 ^a	0.48 $\pm$ 0.02 ^a	-	-
Mean harvest weight (g)	310.6 $\pm$ 33.4 ^a	302.2 $\pm$ 44.3 ^a	-	-
GFY (kg)	14.3 $\pm$ 1.7 ^b	9.3 $\pm$ 0.9 ^a	-	-
DWG (g/day/fish)	2.00 $\pm$ 0.22 ^a	1.95 $\pm$ 0.30 ^a	-	-
Survival (%)	92.0 $\pm$ 4.2 ^b	63.3 $\pm$ 6.6 ^a	-	-
GFY (t/ha/crop)	0.71 $\pm$ 0.07 ^a	0.47 $\pm$ 0.05 ^a	-	-
NFY (t/ha/crop)	0.69 $\pm$ 0.07 ^a	0.44 $\pm$ 0.05 ^a	-	-
Silver Carp				
Mean stocking weight (g)	44.2 $\pm$ 0.73 ^a	45.3 $\pm$ 2.91 ^a	-	-
Total stocking weight (kg)	3.09 $\pm$ 0.05 ^a	3.17 $\pm$ 0.20 ^a	-	-
Mean harvest weight (g)	216.5 $\pm$ 27.6 ^a	262.0 $\pm$ 18.8 ^a	-	-
GFY (kg)	14.57 $\pm$ 2.07 ^a	14.40 $\pm$ 0.34 ^a	-	-
DWG (g/day/fish)	1.15 $\pm$ 0.19 ^a	1.44 $\pm$ 0.14 ^a	-	-
Survival (%)	95.7 $\pm$ 1.7 ^b	79.1 $\pm$ 3.9 ^a	-	-
GFY (t/ha/crop)	0.73 $\pm$ 0.10 ^a	0.72 $\pm$ 0.02 ^a	-	-
NFY (t/ha/crop)	0.57 $\pm$ 0.11 ^a	0.56 $\pm$ 0.02 ^a	-	-
Bighead Carp				
Mean stocking weight (g)	3.0 $\pm$ 0.14 ^a	3.0 $\pm$ 0.50 ^a	-	-
Total stocking weight (kg)	0.06 $\pm$ 0.00 ^a	0.06 $\pm$ 0.01 ^a	-	-
Mean harvest weight (g)	202.3 $\pm$ 65.1 ^a	164.2 $\pm$ 19.5 ^a	-	-

Parameter	Treatment			
	T ₁	T ₂	T ₃	T ₄
GFY (kg)	2.41±0.49 ^a	2.37±0.17 ^a	-	-
DWG (g/day/fish)	1.33±0.43 ^a	1.07±0.13 ^a	-	-
Survival (%)	66.7±14.5 ^a	75.0±12.6 ^a	-	-
GFY (t/ha/crop)	0.12±0.02 ^a	0.12±0.01 ^a	-	-
NFY (t/ha/crop)	0.12±0.02 ^a	0.12±0.01 ^a	-	-
Grass Carp				
Mean stocking weight (g)	3.0±0.33 ^a	3.0±0.00 ^a	-	-
Total stocking weight (kg)	0.03±0.00 ^a	0.03±0.00 ^a	-	-
Mean harvest weight (g)	698.2±136.6 ^a	658.3±50.0 ^a	-	-
GFY (kg)	4.24±0.32 ^a	3.89±0.09 ^a	-	-
DWG (g/day/fish)	4.63±0.91 ^a	4.37±0.33 ^a	-	-
Survival (%)	63.3±6.7 ^a	60.0±5.8 ^a	-	-
GFY (t/ha/crop)	0.21±0.02 ^a	0.19±0.00 ^a	-	-
NFY (t/ha/crop)	0.21±0.02 ^a	0.19±0.00 ^a	-	-
Rohu				
Mean stocking weight (g)	29.8±1.16 ^a	32.9±1.66 ^a	-	-
Total stocking weight (kg)	0.89±0.03 ^a	0.99±0.05 ^a	-	-
Mean harvest weight (g)	312.9±35.3 ^a	384.5±24.2 ^a	-	-
GFY (kg)	8.72±0.84 ^a	10.87±0.54 ^a	-	-
DWG (g/day/fish)	1.89±0.23 ^a	2.34±0.17 ^a	-	-
Survival (%)	93.3±1.9 ^a	94.4±2.9 ^a	-	-
GFY (t/ha/crop)	0.44±0.04 ^a	0.54±0.03 ^a	-	-
NFY (t/ha/crop)	0.39±0.04 ^a	0.49±0.03 ^a	-	-
Mrigal				
Mean stocking weight (g)	17.33±1.17 ^a	17.67±0.33 ^a	-	-
Total stocking weight (kg)	0.35±0.02 ^a	0.35±0.01 ^a	-	-
Mean harvest weight (g)	220.2±30.5 ^a	259.5±31.6 ^a	-	-
GFY (kg)	2.90±0.13 ^a	4.14±0.96 ^a	-	-
DWG (g/day)	1.35±0.20 ^a	1.61±0.21 ^a	-	-
Survival (%)	68.3±9.3 ^a	78.3±11.7 ^a	-	-
GFY (t/ha/crop)	0.15±0.01 ^a	0.21±0.05 ^a	-	-
NFY (t/ha/crop)	0.13±0.01 ^a	0.19±0.05 ^a	-	-
Tilapia				
Mean stocking weight (g)	3.5±0.48	6.5±0.00	6.5±4.48 ^a	3.2±0.11 ^a
Total stocking weight (kg)	0.21±0.03	0.39±0.00	1.31±0.90 ^a	1.28±0.04 ^a
Mean harvest weight (g)	196.1±21.6	279.8±47.5	132.6±7.4 ^a	214.3±5.6 ^b
GFY (kg)	6.76±1.40	11.93±2.77	15.55±0.59 ^a	52.08±1.13 ^b
DWG (g/day/fish)	1.28±0.14	1.82±0.32	0.84±0.07 ^a	1.41±0.04 ^b
Survival (%)	56.7±8.6	72.8±17.1	59.2±4.9 ^a	60.8±2.0 ^a
GFY (t/ha/crop)	0.34±0.07	0.60±0.14	0.78±0.03 ^a	2.60±0.02 ^b
NFY (t/ha/crop)	0.33±0.07	0.58±0.14	0.71±0.06 ^a	2.54±0.06 ^b
Sahar				
Mean stocking weight (g)	7.0±0.14	-	-	-
Total stocking weight (kg)	0.14±0.00	-	-	-
Mean harvest weight (g)	69.4±2.9	-	-	-
GFY (kg)	1.18±0.01	-	-	-

Parameter	Treatment			
	T ₁	T ₂	T ₃	T ₄
DWG (g/day/fish)	0.42±0.02	-	-	-
Survival (%)	85.0±2.2	-	-	-
GFY (t/ha/crop)	0.06±0.00	-	-	-
NFY (t/ha/crop)	0.05±0.00	-	-	-

Mean values in a row with the same superscript are not significantly different ($\alpha = 0.05$).

There was no significant difference in average temperature and Secchi disk depth among treatments during the experimental period (Table 3, $p>0.05$); however, dissolved oxygen was significantly higher in T₃ than other treatments ($p<0.05$).

Table 3: Water quality parameters (mean ±SE with range in parentheses) of different treatments

Parameters	Treatments			
	T ₁	T ₂	T ₃	T ₄
Water temperature (°C)	29.2±0.1 ^a (17.6-32.5)	29.2±0.1 ^a (17.1-32.3)	28.9±0.3 ^a (17.0-34.2)	28.9±0.1 ^a (16.6-31.9)
Dissolved oxygen (mg/L)	5.5±0.1 ^a (3.3-10.0)	5.3±0.3 ^a (2.6-10.8)	6.6±0.2 ^b (2.6-14.1)	5.2±0.3 ^a (1.4-11.2)
pH	7.8 (6.8-8.7)	7.8 (6.7-8.7)	8.3 (7.2-9.8)	8.0 (7.2-9.0)
Secchi disk depth (cm)	27.0±3.0 ^a (13.3-46.7)	29.0±3.1 ^a (18.3-48.3)	34.9±2.9 ^a (20.0±53.3)	37.6±3.2 ^a (25.0-60.0)

Mean values in a row with same superscript are not significantly different ($\alpha = 0.05$).

All carp polyculture and tilapia monoculture systems differed in economic performance, with the treatment monosex tilapia with feed being most profitable. The variable costs in all treatments consisted of seed, feed, lime, urea, and DAP (Table 4). Cost of seed was significantly different among treatments ($p<0.05$), whereas cost of feed was not significantly different among treatments ($p>0.05$). There was no significant difference in all other variable costs among different treatments ($p>0.05$). Total input cost and total output were significantly lower in T₃ than other treatments. The gross profit margin was significantly lower in T₃ than other treatments, whereas there was no significant difference in gross profit margin among T₁, T₂ and T₄ (Table 4).

Table 4: Economic analysis (in USD) for each treatment. Data based on a 200 m² pond area and culture period of 150 days

Variable	Treatment			
	T ₁	T ₂	T ₃	T ₄
Seed	14.9±0.0 ^d	14.5±0.0 ^c	3.8±0.0 ^a	7.6±0.0 ^b
Feed	57.2±7.4 ^b	58.9±2.3 ^b	0.0±0.0	41.6±3.0 ^a
Lime	1.7±0.0 ^a	1.7±0.0 ^a	1.7±0.0 ^a	1.7±0.0 ^a
Urea	3.9±0.0 ^a	3.9±0.0 ^a	3.9±0.0 ^a	3.9±0.0 ^a
DAP	6.9±0.0 ^a	6.9±0.0 ^a	6.9±0.0 ^a	6.9±0.0 ^a
Total Input	84.5±7.4 ^c	85.9±2.3 ^c	16.3±0.0 ^a	61.7±3.0 ^b
Total Output	134.9±11.6 ^b	135.6±7.8 ^b	37.0±1.4 ^a	124.0±2.7 ^b
Gross Margin	50.4±8.2 ^b	49.7±6.8 ^b	20.7±1.4 ^a	62.3±4.7 ^b
Gross Margin (US\$/ha)	2521.4±411.8 ^b	2483.2±339.1 ^b	1036.9±70.7 ^a	3115.6±237.5 ^b

Mean values in a row with the same superscript are not significantly different ($\alpha = 0.05$).

DISCUSSION

The present study evaluated the performance of Nile tilapia under monoculture and polyculture systems with carps and sahar under farmer-managed conditions in Nepal. The results clearly demonstrate that culture systems incorporating Nile tilapia, either as part of carp-based polyculture or as all-male tilapia monoculture with feeding, substantially outperform unfed tilapia monoculture in terms of fish yield and economic returns. Consistent with our previous on-station trial (Pandit et al. 2023), these findings confirm that tilapia-based systems can enhance pond productivity and diversify aquaculture practices in Nepal.

In the present study, the growth, production, and survival of carps and tilapia were comparable to those reported in the on-station trial (Pandit et al. 2023). However, sahar exhibited a higher growth rate (0.42 g/fish/day) than in the on-station trial (0.13 g/fish/day). The daily weight gain of sahar in the on-farm trial was still lower than tilapia-sahar polyculture systems (0.3-0.4 g; Shrestha et al. 2011) and growth rates achieved in other culture systems (0.55-0.77 g; Islam 2002). In the on-farm trial, the combined gross fish yield in carp treatments (6.7-6.9 t/ha/yr) was slightly higher than the on-station trial (5.8-6.5 t/ha/yr) as well as the national average of carp polyculture (5.5 t/ha/yr; MoALD 2023).

The significantly lower gross and net fish yields observed in tilapia monoculture without feeding (T_3) indicate that fertilization alone was insufficient to support optimal tilapia growth at the tested stocking density. Although tilapia are efficient plankton feeders, the available natural productivity in fertilized ponds did not meet the nutritional demands required for higher growth rates, resulting in reduced biomass production. In contrast, tilapia monoculture with supplemental feeding (T_4) achieved significantly higher growth rates, yields, and feed conversion efficiency, highlighting the importance of external feed inputs for maximizing tilapia production under Nepalese climatic conditions. Similar trends have been reported in other tropical and subtropical regions, where fed tilapia systems consistently outperform unfed systems (Diana 2012).

The comparable combined net fish yields among carp-tilapia-sahar polyculture (T_1), carp-tilapia polyculture (T_2), and tilapia monoculture with feeding (T_4) suggest that these systems are equally effective in enhancing pond productivity. Importantly, the inclusion of tilapia did not negatively affect the growth or production of carps, as no significant differences were observed in carp performance between T_1 and T_2 . This indicates effective niche differentiation and resource partitioning among species, allowing efficient utilization of pond natural productivity. Plankton-feeding behavior of Nile tilapia may also have contributed to nutrient recycling and stabilization of water quality, supporting overall system performance.

Water quality parameters remained within acceptable ranges for fish culture across all treatments (Boyd 1990). The higher dissolved oxygen concentrations observed in T_3 are likely attributable to lower standing biomass and reduced respiratory demand rather than superior system functioning. The absence of significant differences in temperature, pH, and water transparency among treatments further suggests that the intensified systems did not compromise pond environmental conditions.

The promising survival and growth of sahar in the polyculture system is a notable outcome of this study. As an endangered native species, its integration into carp polyculture demonstrates the feasibility of conservation-oriented aquaculture. Pond-based rearing of sahar may reduce fishing pressure on wild populations while contributing to species diversification and improved utilization of pond resources. Additionally, its inclusion alongside tilapia may assist in managing excessive tilapia recruitment, a common challenge in mixed-sex tilapia culture. Jaiswal (2010) and Shrestha et al.

(2011) also showed that the average number and weight of tilapia recruits in treatments with sahar was lower than with tilapia and carp only.

Economic analysis revealed that all-male tilapia monoculture without feeding was significantly less profitable than all other treatments, despite its lower input costs. In contrast, carp-tilapia-sahar polyculture, carp-tilapia polyculture, and tilapia monoculture with feeding generated comparable and substantially higher gross profit margins. These results suggest that farmers have multiple viable production options depending on resource availability, risk tolerance, and market demand. Polyculture systems offer species diversification and stability, whereas all-male tilapia monoculture with feeding provides higher individual fish growth and management simplicity.

Overall, the findings confirm that integrating Nile tilapia into existing carp systems or adopting all-male tilapia monoculture can significantly improve productivity and farm profitability without compromising environmental sustainability under Nepalese on-farm conditions.

CONCLUSION

This study demonstrates that carp-tilapia-sahar polyculture, carp-monosex tilapia polyculture, and monosex tilapia monoculture with supplemental feeding are productive, economically viable, and environmentally sustainable alternatives to traditional carp polyculture in Nepal. In contrast, monosex tilapia monoculture without feeding produced significantly lower yields and economic returns, systems incorporating supplemental feeding or species diversification achieved superior and comparable performance. The successful culture of sahar under polyculture conditions highlights its potential role in conservation-oriented aquaculture and native species utilization. Adoption of these improved culture systems can enhance pond productivity, increase farmer income, diversify species composition, and support sustainable aquaculture development in Nepal. Future research should focus on optimizing stocking densities, feed management strategies, and seasonal production cycles, as well as evaluating long-term environmental impacts and large-scale adoption by farmers.

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REFERENCES

- AOAC. (1980). Methods of analysis, 13th edition. Association of Official Analytical Chemists, Washington DC, USA. 1018 p.
- APHA. (1985). Standard methods for the examination of water and wastewater, 16th Edition. American Public Health Association (APHA), American Water Works Association, Water Environment Federation. pp. 445-446.
- Boyd, C.E. (1990). Water quality in ponds for aquaculture. Alabama Agricultural Experiment Station, Auburn University, Alabama. 482 p.
- Diana, J.S. (2012). Some principles of pond fertilization for Nile tilapia using organic and inorganic inputs. In: Aquaculture Pond Fertilization: Impacts of Nutrient Input on Production, 1st Edition, C.C. Mischke (ed.). John Wiley and Sons, Inc., Hoboken. pp. 163-177.
- Islam, M.S. (2002). Evaluation of supplementary feeds for semi-intensive pond culture of mahseer (*Tor putitora*). Aquaculture 212:263-276. [https://doi.org/10.1016/S0044-8486\(02\)00194-1](https://doi.org/10.1016/S0044-8486(02)00194-1).
- IUCN. 2017. IUCN Red List of Threatened Species. Accessed from www.iucnredlist.org

- Jaiswal, R. (2010). Integration of tilapia (*Oreochromis niloticus*) and sahar (*Tor putitora*) in carp polyculture system. Master of Science Thesis, Institute of Agriculture and Animal Science, Nepal.
- MoALD. (2023). Statistical information on Nepalese agriculture 2021/2022. Ministry of Agriculture and Livestock Development (MoALD). Singha Durbar, Kathmandu, Nepal.
- Pandit, N.P., Bista, J.D., Ranjan, R. and Shrestha, M.K. (2018). Research status of sahar (*Tor putitora*) aquaculture in Nepal. *Nepalese Journal of Aquaculture and Fisheries* 5: 22-33.
- Pandit, N.P., Ranjan, R. and Shrestha, M.K. (2023). A comparison of monoculture and polyculture of Nile tilapia (*Oreochromis niloticus*) with carps and sahar (*Tor putitora*). *Nepalese Journal of Aquaculture and Fisheries* 10: 43-51. <https://doi.org/10.3126/njaf.v10i1.78790>
- Shang, Y.C. (1990). *Aquaculture Economics Analysis: An Introduction*. World Aquaculture Society, Baton Rouge, Louisiana. 211 p.
- Shrestha M.K., Sharma, R.L., Gharti, K. and Diana, J.S. (2011). Polyculture of sahar (*Tor putitora*) with mixed-sex Nile tilapia. *Aquaculture* 319:284-289. <https://doi.org/10.1016/J.AQUACULTURE.2011.07.005>.
- Shrestha, M.K., Bhandari, M.P., Diana, J.S., Jaiswal, R. Mishra, R.N. and Pandit, N.P. (2018). Positive impacts of Nile tilapia and predatory sahar on carp polyculture production and profits. *Aquaculture and Fisheries*, 3(5): 204-208. <https://doi.org/10.1016/j.aaf.2018.06.002>.
- Shrestha, M.K., Pandit, N.P. and Bhujel, R.C. (2022). Sustainable fisheries and aquaculture for food and nutrition security in Nepal. p. 315-333. In: J. Timsina, T.N. Maraseni, D. Gauchan, J. Adhikari and H. Ohja (Eds.), *Agriculture, Natural Resources and Food Security: Lessons from Nepal*. Sustainable Development Goals Series, https://doi.org/10.1007/978-3-031-09555-9_18.
- Shrestha, M.K., Jaiswal, R., Liping, L. and Diana, J.S. (2012). Incorporation of tilapia (*Oreochromis Niloticus*) and sahar (*Tor Putitora*) into the existing carp polyculture system of Nepal. Technical Report: Investigation 2009-2011. AquaFish Innovation Lab, Oregon State University, Corvallis, Oregon. pp. 38-52.

