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Research article

Bio-economic evolution of snakeheads and Indian major carps culture in IMTA system

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ABSTRACT

An experimental study was carried out for a period of six months to assess the commercial culture potentiality of striped snakehead (*Channa striatus*) over Indian Major Carps (IMCs) in improved Integrated Multi-Trophic Aquaculture (IMTA) system. Characteristics of snakehead (*Channa striatus*) make it a desirable culturable fish in IMTA system. The experiment was done in two steps-nursery stage (2 months) and grow-out stage (4 months). In the nursery stage, the stocking density was 30 nos/m^3 (2.3±0.42 g). Larvae were fed with finely granule formulated feed containing 43.4% protein at 5% body weight which had FCR of 1.3. The survival rate was 67% in this stage. After two months, 20 nos/m^3 fry were collected from the larval rearing tank and their average body weight was 25.6±1.9 g. The collected fishes were transferred into grow-out pond and to utilize all the trophic level of the water, 5 tilapia (*Oreochromis mossambicus*), 2 silver carp (*Hypophthalmichthys molitrix*), 1 sarpunti (*Barbonymus gonionotus*) and 1 rui (*Labeo rohita*) of comparatively larger size than snakeheads were added in each pond. Stinging catfish (*Heteropneustes fossilis*) was cultured in cages at 100 nos/ft^3 stocking density where snails produced in the bottom were used as a major feed ingredient for catfish. Four floating trays, each 0.11 m^2 in surface area, were placed in the ponds for growing lettuce. In grow-out stage, formulated pelleted feed (FCR 1.4) with 34.95% protein was fed at 3% body weight. Here about 93% survival rate was found in grow-out phase. At the end, 25 Kg snakehead/decimal was harvested from improved IMTA system where IMCs were produced at 20 Kg/decimal in traditional IMTA system. But no significant difference ($P < 0.05$) was found in production of stinging catfish and vegetables between the improved and traditional IMTA system. The improved IMTA system possessed a significantly lower ($P < 0.05$) operating ratio (59%) than the traditional IMTA system (65%). Return on sales ratio was 41.18% in improved IMTA which was significantly higher ($P < 0.05$) and confirmed the system to bear the burden of increased cost of production but the profit margin was also higher. Benefit-Cost Ratio (BCR) was 1.7 in improved IMTA system which was significantly higher ($P < 0.01$) than traditional IMTA system (1.54). The innovated improved IMTA system can provide around 16% more profit compared to traditional IMTA system from per decimal pond area. This suggests that IMTA can be promoted through action research and field trial with potential fish farmers towards sustaining economic viability and food security of the poor people.

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1. INTRODUCTION

Integrated multi-tropic aquaculture (IMTA) utilizes the by-products, including waste, from one aquatic species as inputs (fertilizers, food etc.) for another. The IMTA concept is extremely flexible as it can be applied from open water to freshwater closed system as well as land-based systems, where appropriate organisms are chosen according to their ecosystem and economic value or potential (Barrington, 2009). Troell (2009) recommended that future expected increases in energy prices and costs for aqua feeds can be facilitated by the development and practice of integrated systems, which will also strengthen the environmental regulations. Neori et al. (2000) conducted an experimental integrated system for the intensive land-based culture of abalone, seaweed and fish with the goals to achieve higher yields, nutrient recycling, reduce water use and nutrient discharge. Kibria and Haque (2018) found the production of snail and water spinach in IMTA production contributed to the bio-mitigation process of organic and inorganic waste, keeping the water quality within suitable conditions for fish culture. The highest yields of the carps and stinging catfish in the cage in ponds were obtained in IMTA ponds. Chopin et al. (2012) recommended that to develop efficient food production system, it will be important to understand and use the duality of Most commercial snakehead culture relies on the capture of wild fry, which is trained to accept prepared feed consisting of trash fish paste and rice bran or wheat flour (Diana et al., 1985). These feeds have significant disadvantages as they cannot be kept easily and because of the supply of trash fish is often limited, seasonal and unreliable (Wee, 1982). Therefore, using formulated pelletized feed is a vital factor for improved snakehead farming. Although the snakehead is a relatively hardy cultured species because of the high rate of mortality by cannibalism among juveniles but this can be reduced from 83% to 43% by using formulate feed, when the daily feeding rate is maintained at 15% of the larger fish's body weight (Qin and Fast, 1996; Kubitza and Lovshin, 1997). Formulated feeds do not have the characteristics of live feed organisms, so attractant is needed to facilitate a feeding response. Therefore, fish require being more attracted to the formulated feed relative to cannibalism (Kubitza and Lovshin, 1999). Chemo attractants and feeding nutrients essential when limiting/ polluting (when in excess) producing them in moderation by engineering the system, so that they can be partially recaptured while maintaining their concentration optimal for healthy and productive ecosystems in small scale aquaculture pond. Abreu et al. (2009) found that Integrated Multi-Trophic Aquaculture (IMTA) designed to mitigate the environmental problems caused by several forms of fed aquaculture. After some experimental studies in Chile, *Gracilaria chilensis* was recommended as an efficient bio-filter in IMTA systems. IMTA results in benthic nutrient fluxes, reduced inorganic sulfur in sediments, distributed dissolved inorganic selenium, and influenced nutrient cycling which results in higher kelp growth (Fang, 2016). Stimulants are an important means of reducing feed wastage by improving initial feeding and feed palatability (Lee and Peter, 1994). Abol- Munafi et al. (2004) stated that during the first month, *C. striatus* larvae should be fed with *Artemia* and *Moina* since formulated feed was much less acceptable and can cause low survival rate and growth rate. However, Qin et al. (1997a) concluded that *C. striatus* could be trained to eat

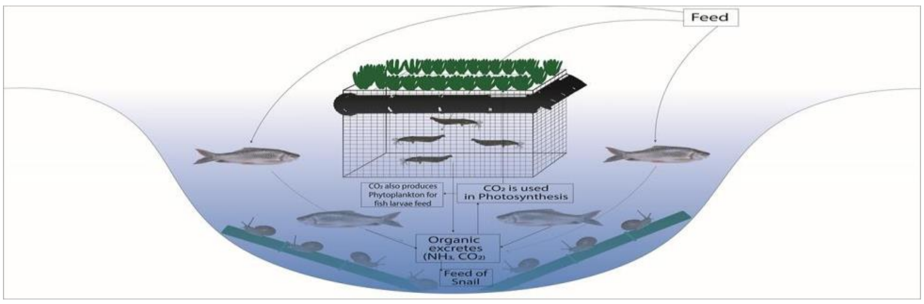

Figure 1: Traditional IMTA

formulated feeds using two methods. Method 1: feed the larvae with *Artemia* nauplii supplemented with formulated feed for 30 days and slowly stop giving live food over a 7-10 days period. Method 2: feed the larvae with *Artemia* nauplii only for 30 days and feed *Artemia* and formulate feed for following 7-10 days. After they can be adapted to consume formulated feed, large quantities of snakehead can be cultured on small land areas using little water as they are high ammonia tolerant species (Qin et al., 1997). In many countries it is one of the most common staple food fishes. In the past, most of the supply of snakehead came from capture fisheries. But in recent years, it has drawn attention for being cultured domestically. Due to the suitability of the fish for culture by virtue of its air- breathing characteristic and hardiness along with high tolerance level to dissolved ammonia, have created keen interest in farming the species in IMTA system (Wee, 1981). Selecting appropriate species and sizing the various populations is necessary for better profitability by allowing the biological and chemical processes involved to achieve a stable balance, mutually benefiting the organisms which increase growth and production. Capital-budgeting results suggest that using the waste of one crop as feed for another can increase profits.

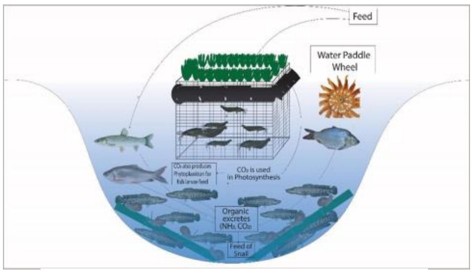

Figure 2: Improved IMTA

Scenario analysis also indicates that financial risks are reduced if weather-related or market risks for the various species are not correlated. Surveys indicate a positive perception to integrated multi-trophic aquaculture by the public, which should assist integrated multi-trophic aquaculture (Ridler et al., 2007). Also their dark skin is usually sold separately which is good for soup (Davidson, 1975). Its flesh is claimed to be rejuvenating and widely consumed for its nutritional value as well as for its beneficial effect in wound healing (Mat et al., 1994; Wee, 1982). It is also well known for its therapeutic effect and pain reduction due to osteoarthritis (Michelle et al., 2004). It is also an excellent source of dietary protein for human (Gam et al., 2005).

The present study was undertaken to make a systematic comparison on Bio-economic evaluation of snakeheads (*Channa* spp.) culture in the traditional IMTA system as a replacement of Indian Major Carps (IMCs) in freshwater pond. Because Snakeheads have a high market value, rapid growth, tolerance to high stocking rate, medicinal value and utilization of atmospheric oxygen for respiration in oxygen-depleted water. The ultimate aim of the proposed project was to develop an improved IMTA system with a better profit margin from per unit area. The specific objectives of the proposed project are as follows:

• To improve the traditional IMTA system for a better profit margin.
• To develop a viable integrated culture of catfish together with snakehead and hydroponics
• To stimulate the growth of snakehead in IMTA system by producing a durable formulated feed.

2. MATERIALS AND METHODS

Experimental site

The proposed project was carried out both in the laboratory and field. Field work was conducted in the hatchery of the Institute of Coastal Biodiversity, Marine Fisheries and Wildlife Conservation Research Center, CVASU, Cox's Bazar with the endure of proper facilities. Laboratory work was carried out at Faculty of Fisheries, Chattogram Veterinary and Animal Science University. The whole experimental period was 6 months to ensure the entire target species attain marketable size.

Experimental design

The experiment was done in two steps- nursery stage (2 months) and grows out stage (4 months). The larvae of snakeheads (*Channa striatus*) were reared in four different tanks each with a water holding capacity of 800L. Continuous aeration supply and regular water exchange were required in larval rearing tanks. After two months of larval rearing, the collected juveniles were transferred into a previously prepared IMTA pond. One small cage (1×1×1 ft^3) was placed in the pond to raise stinging catfish (*Heteropneustes fossilis*). Five bamboo splits, each 1m long were placed in the pond as a temporary shelter for snails, covering an area of $1m^2$ of the pond bottom in a square array of three lines and embedded into the bottom at 45^0 angles. On a floating tray ($0.11m^2$), lettuce was planted to decrease the organic load from the experimental pond. Some IMCs were also stocked to utilize all the trophic levels.

Collection and conditioning of fish

Snakehead fish seeds were collected from a fish farm located in Ishwarganj, Mymensingh and other fish seeds were collected from nearby hatcheries of the experimental area. After collection, seeds were brought in the experimental area as soon as possible by following the modern fish transportation technique. To minimize the stress after transportation, conditioning was done before releasing larvae to adjust them with the new confined experimental environment.

Stocking of fish seed

The Stocking density was different in the nursery and grow-out stage. The stocking density was 30 nos/m^3 (2.3±0.42 g) in nursery stage. Therefore, continuous aeration supply and regular water exchange were done. In grow out stage, Snakehead fry were stocked at 120 nos/decimal (25.6±1.9 g) as a replacement of Indian major carps in the open area of the pond. Shing (*Heteropneustes fossilis*) were stocked at a density of 100 nos/ ft^3. To utilize all the trophic levels of the water, 5 tilapia (*Oreochromis mossambicus*), 2 silver carp (*Hypophthalmichthys molitrix*), 1 sarpunti (*Barbonymus gonionotus*) and 1 rui (*Labeo rohita*) of comparatively larger size than snakeheads were stocked in the pond.

Figure 3: Larval rearing tank

Aquatic plant cultivation in floating trays

Lettuce, an aquatic plant component of IMTA was cultivated on plastic trays supported by locally available empty plastic water bottles, floating on the water surface. A piece of synthetic net was placed on the bottom of each tray.

Feed formulation and feeding

Two different diets were formulated during the experiment, one for the nursery phase and another for the grow-out phase. The diets contained different ingredients and protein ratio, optimum for carnivorous fish culture. Larvae were fed with finely granule formulated feed containing 43.4 % protein at 5% body weight. The feeding frequency was five times per day and the total amount of feed required was 30 g/fish in this stage. In grow out stage formulated pelleted feed with 34.95% protein content was fed at 3% body weight. The calculated daily ration was divided into equal halves and given twice in a day. About 280 g of formulated feed was required in this stage for individual fish. The major feed ingredient was fish-meal in the both nursery and the grow-out stage feed. Both natural and artificial attractants were used to formulate the feed to facilitate feeding response, ultimately which reduced cannibalism. Fish were cultured until they attain the marketable size.

Data collection

Feed cost, growth rate, percent weight gain, food conversion ratio and other additional culture related cost, finally bio-economic evolution and comparison with traditional IMTA system from the experiment was recorded.

Figure 4: Data collection

Table 1: Ration at nursery stage

Sl. No	Ingredients	Quantity	Protein percent	Diet Formulation	Protein in diet	Cost
1	Fish meal	475 gm	50%	45%	23.75%	38/-
2	Soybean meal	175 gm	42%	16.4%	7.35%	6.13/-
3	Rice bran	175 gm	12%	16.4%	2.1%	3.15/-
4	Maize bran	175 gm	10%	16.4%	1.75%	2.8/-
5	Vitamin-mineral premix	10 gm	---	1%	---	3/-
6	Di-calcium phosphate	20 gm	---	2%	---	1.6/-
7	Binders	10 gm	---	1%	---	1.5/-
8	Methi	10 gm	---	1%	---	0.25/-
9	Molasses	10 ml	---	---	---	0.34/-
10	Fish oil	5 ml	---	---	---	4/-
11	Attractants (Artificial/natural)	(5/50) gm	---	1/5%	---	20/-
Total				100%	34.95%	80.77/-

Table 2: Ration at grow out stage

Sl. No	Ingredients	Quantity	Protein percent	Diet formulation	Protein in diet	Cost
1	Fish meal	750 gm	50%	71%	37.5%	60/-
2	Soybean meal	100 gm	42%	9.5%	4.2%	3.5/-
3	Rice bran	100 gm	12%	9.5%	1.2%	1.8/-
4	Maize bran	50 gm	10%	5%	0.5%	0.8/-
5	Vitamin-mineral premix	10 gm	---	1%	---	3/-
6	Di-calcium phosphate	20 gm	---	2%	---	1.6/-
7	Binders	10 gm	---	1%	---	1.5/-
8	Methi	10 gm	---	1%	---	0.25/-
9	Molasses	10 ml	---	---	---	0.34/-
10	Fish oil	5 ml	---	---	---	4/-
11	Attractants (Artificial/natural)	(5/50) gm	---	1/5%	---	20/-
Total			---	100%	43.4%	96.8/-

Statistical Analysis

Collected data were analyzed with the aid of Microsoft Office Excel software for comparative study of the research project. As it was a biological experiment, to analyze the collected data both 95% and 99% level of significance were used.

3. RESULTS

Feed Conversion Ratio (FCR)

Channa striatus is a carnivorous fish. They prey on small live fishes. So, high protein feed was required as a replacement for their live feed. The feed cost was higher because of high protein percentage. Handmade attractants included feed costs 80 taka where per kg fish production needed 1.5kg of feed costing around 130 taka. The market price of per kg fish was around 300 taka. Domesticated fishes performed best while given floating feed. But placing a tray below the level of 4-5 inches of the water column also showed the better results. In larval rearing stage and grow out stage the FCR value was 1.3 and 1.4.

Behavior

The behavioral observation of snakehead was done under this experiment considering feed acceptance depending on protein percentage, feed type and condition of the feed. Snakehead fed with commercial feed where the protein percentage is higher than 40% in the larval stage but in grow-out stage protein percentage is comparatively lower than the larval stage about 34.95%. Floating feed performed best due to their feeding behavior. In case of sinking feed, when the trays were placed less than 4-5 inches in the water column also showed good result. The feed loses its acceptance when it sinks rapidly.

Survival Rate and growth

Snakehead larvae were stocked at 30nos/m^3 where the initial weight of larvae was (2.3±0.42 g). About 67% survival rate was found in the larval rearing stage. After two months, 20 nos/m^3 were collected from the nursery pond when their average body weight was 25.6±1.9 g. Then 120 juveniles/decimal were stocked in grow out pond where the survival rate was 93%.

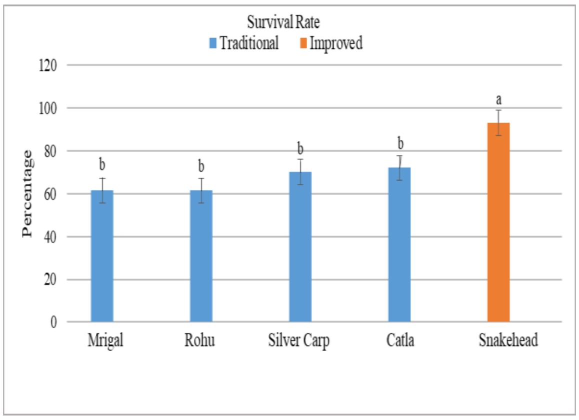

Figure 5: Survival rate in different IMCs and snakehead

In the end, 110 fishes of 25 Kg were harvested from one decimal pond. The mean weight of individual fish was 230 g. Different IMC's like rui, catla, mrigal and silver carp have different growth-rates. In the experiment it was observed that the Specific Growth Rate of snakehead (*Channa striatus*) was about 1.52 which was higher than the IMCs cultured in traditional IMTA.

Bio-Economic Analysis

A comparison of income and expenditure of the traditional IMTA and improved IMTA in a one decimal pond is given below-

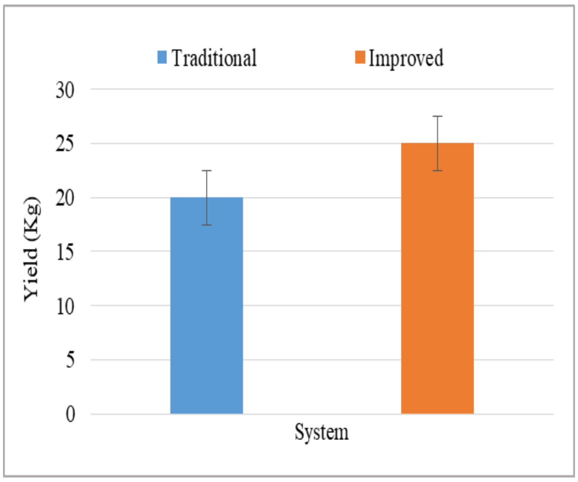

Figure 6: Production in traditional and Improved IMTA system

Table 3: Comparison between the expenditure and return of traditional and improved IMTA

Traditional IMTA (for one decimal)		**Improved IMTA (for one decimal)**	
Expenses of expenditure	**Amount (Taka)**	**Expenses of expenditure**	**Amount (Taka)**
Cage setup and pond preparation, Fertilization etc.	500/-	Cage setup and pond preparation, Fertilization etc.	500/-
Fry Stocking (Rui, Catla, Mrigal, Shing)	500/-	Fry Stocking (Snakeheads, Rui, Catla, Sarpunti, Shing)	500/-
Feed cost (Until the fishes get marketable size)	2000/-	Feed cost (Until the fishes get marketable size)	2500/-
Other miscellaneous (Transportation, Data collection, Net, harvesting, pumping of water, Aquaponics setup cost, labour cost etc.)	2000/-	Other miscellaneous (Transportation, Aeration, Data collection, Net, harvesting, pumping of water, Aquaponics setup cost, labour cost etc.)	3500/-
Total expenditure	5000/-	Total expenditure	7000/-

Table: Continue…

Traditional IMTA		**Improved IMTA**	
Income sector	**Amount (Taka)**	**Income sector**	**Amount (Taka)**
Cash crops (IMCs 20 kg*200 tk)+ Shing 6kg *500tk)+ Vegetables=800	4000+3000+800	Cash crops (IMCs 3 kg*200 tk)+ Shing 6kg *500 tk)+ Vegetables=800+Snakeheads (25kg *300)	600+3000+800+7500
Total income	7,700/-	Total income	11,900/-
Total expenditure	5000/-	Total expenditure	7000/-
Net Profit	2,700/-	Net Profit	4,900/-
BCR	1.54	BCR	1.7
Operation Ratio	65%	Operation Ratio	59%
Return on Sale	35%	Return on Sale	41%

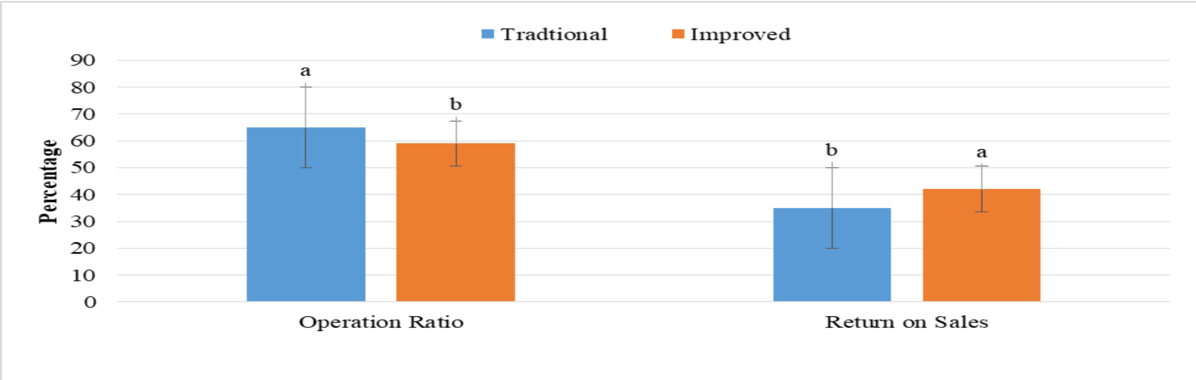

Figure 7: Bio-economic analysis of traditional and improved IMTA system

4. DISCUSSION

Growth

Aquaculture research and extension started in Bangladesh with very low stocking density of 5000 or fewer individual's ha^{-1} (Rajbangshi and Shrestha, 1980; Sharma et al., 1985; Sharma and Das, 1988; Sharma, 1989, 1990; Mazid et al., 1997), which has been greatly increased by several research and development projects. For example, stocking density in carp polyculture was 20,000 fish ha^{-1} at the research level (Haque et al., 2014; Wahab et al., 2014), and was 55,000–60,000 fish ha^{-1} at the farmers' level (Nahid et al., 2012; Ali et al., 2013). This increasing intensification indicates the environmental implications of pond aquaculture on one hand, on the other hand, it shows huge productivity potential to grow diversified aquaculture products applying IMTA principles in the pond, which is experimented in this study and discussed. Different IMC's like rui (*Labeo rohita*), catla (*Gibelion catla*), mrigal (*Cirrhinus cirrhosus*) and silver carp (*Hypophthalmichthys molitrix*) have different growth rate. In traditional IMTA system, total IMCs production was 20 kg/decimal tank but in case of improved IMTA system snakehead production was higher than IMCs about 25 kg/decimal tank (Figure 6). This was possible because the polyculture of the snakehead, carps and stinging catfish worked well where the production food organisms were enhanced by co-species; as a result, the total production per unit of area was also increased. One previous study of IMTA system showed that specific growth rate of catla, silver carp, rohu and mrigal were 1.07, 1.19, 1.21 and 0.90 (Kibria and Haque, 2018). In the experiment it was observed that the specific growth rate (%per day) of snakehead (*Channa striatus*) was higher than all of them, about 1.26 (mean initial weight 2.75 g and mean final weight 230 g) where snakehead was stocked in high density (120 fry/decimal). Lettuce is a very popular vegetable in Bangladesh as human food, and all parts except roots of the young lettuce plant are edible. According to our observation in the IMTA ponds, the growth of lettuce was medium in scale; the root did not touch the pond bottom, rather took nutrients under submerged conditions. This further confirmed that lettuce exhibited a bio-mitigation process, and kept the concentrations of nitrogenous waste within suitable ranges. But no significant difference ($P < 0.05$) was found in production of stinging catfish and vegetables between the improved and traditional IMTA system because of the same environmental condition, survival, and nutrient recycling.

Survival Rate

In the experiment, 65% survival rate was observed in larval stage. About 93% larval survival rate was found in the experiment at grow out stage and at the end 110 fishes of 25 Kg were harvested from one decimal tank. On the other hand, in grow out stage survival rate of catla, silver carp, rui and mrigal in IMTA system were 71.94%, 70.04%, 61.43% and 61.38% (Kibria and Haque, 2018). And this consequence concluded that, the survival rate of snakehead was significantly higher ($P < 0.05$) than IMCs in IMTA system (Figure 5). Due to the high stocking density, release of excreta and uneaten particle level in the culture area, ammonia level was higher than the normal. This situation cannot create a huge problem in the culture of *Channa* species because this species possesses an air breathing organ (Vivekanandan, 1977) by which they take oxygen from the air. Using different artificial and natural attractants made the feed more attracted by the target species that increased both FCR and FCE value which not only decreased the waste production but also provided better culture environment. Moreover, it reduced mortality which usually occurs by juvenile cannibalism. And the ultimate consequence was higher survival rate of snakehead.

Feed Conversion Ratio (FCR)

However, in semi-intensive and intensive farming operations, feeds and/or fertilizers account for 40–80% of the total operating costs (De Silva and Hasan, 2007). Therefore, strategies are needed to reduce the amount and cost of feed inputs to provide a good profit margin (Wahab et al., 2014). Being a carnivorous species *Channa striatus* prefers high protein feed. There was positive impact on growth and survival rate of larvae when formulated feed with more than 40% protein content was supplied. It was found that the quality and quantity of feed as well as the feeding regime is important for efficient feed utilization. Feed utilization was higher in case of both floating and sinking feed applied on a tray in the water column.

Bio-Economic Analysis

In the present study, the operating ratio is considered one of the economic efficiency parameters for the use of fixed and variable assets and illustrates the ability of systems to service their cash obligations for the production process. A low percentage for operating ratio shows the acceptable economic terms the farm (Scott et al., 1993; Helal and Essa, 2005; Holliman, 2006). In the improved IMTA system the production process was going efficiently other than traditional IMTA system, because it possessed significantly lower ($P < 0.05$) operating ratio about 59% but in traditional IMTA system operating ratio was 65% (Figure 7) which confirmed that improved IMTA system is economically acceptable.

Return on sales is one of the administrative and technological proficiency parameters. Whenever this ratio increase this indicates, administrative capacity at reduced costs or increased production volume (Goodman, 2011). This ratio was significantly higher ($P < 0.05$) in improved IMTA (41.18%) than traditional IMTA systems (35.06%). These results confirm the ability of the improved IMTA system to bear the burden of increased costs of production because the profit margin was also higher (Figure 7). Benefit cost ratio was also higher in the improved IMTA system (1.7) than traditional IMTA system (1.54). This indicates the efficiency of improved IMTA system to achieve high profit. The main purpose of the experiment was to find out the fact that the improved IMTA system provides 16% more profit from per decimal pond area than the traditional IMTA and the culture suitability of *Channa striatus* in IMTA system. Though both the improved and traditional IMTA are profitable business but here presence difference when considering the total profit margin. Traditional IMTA system resulted in significantly lower ($P < 0.01$) benefit cost ratio compared to improved IMTA system. Production of fish, feed utilization, waste utilization, and environmental parameters were much better in improved IMTA.

5. CONCLUSION

Aquaculture area is decreasing due to the conversion of water-body into urban house facility development for the growing population. In this circumstance, it is high time to make a small aquaculture pond area more productive than before. To get higher production and profit, proper use of all the trophic levels in a pond ecosystem is essential which can be earned by IMTA system. To make environment friendly aquaculture competitive, it is necessary to raise its revenues. By exploiting the extractive capacities of co-cultured lower trophic level taxa, the farm can obtain added products that can outweigh the added cost involved in constructing and operating an IMTA farm. The waste nutrients are considered in integrated aquaculture not a burden but a resource, for the auxiliary culture of bio-filters. Mitigation of effluents through the use of bio-filters which are suited to the ecological niche of the aquaculture site. This can solve a number of environmental challenges. Proper species selection is also very much important in this regards. Culture in high stocking density, less disease attack, high growth rate, high market demand, low feed costs etc. are important for the species selection. Snakeheads are such important cultivable species in this regards. High local market demand and price of Snakeheads makes it a suitable aquaculture species. The most important concern of this proposed project was to develop an improved IMTA technology using snakeheads in an integrated fish polyculture system for better profit earning by small scale fish farmer. The result of this project provides solid information about the cultivation of the snakeheads as a replacement of the major carps as a demandable and high price species. High productivity, easy maintenance, low disease risk makes this experiment successful. At the end of this experiment, a viable culture system has developed for snakehead culture in small scale pond and/tank as a replacement of IMCs in IMTA system.

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