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USE OF DITCH-DIKE SYSTEM IN LOW LYING AREAS TO IMPROVE LIVELIHOODS OF FARMERS OF BANGLADESH

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Abstract

The people living in low lying areas in the southern part of Bangladesh are vulnerable due to repeated water-logging over the last 10 years. The application of pond-dike system in flood-prone low-lying areas may be a high potential for improving livelihoods of poor households. In this purpose, an experiment was conducted to evaluate the growth performance and production of different fish species in monoculture (*tilapia* and *shing*) and polyculture (*rohu, catla, silver* carp, *pangus*, and grass carp) systems using commercial fish feeds to determine a profitable fish culture technique in pond-dike system in low lying area. The fish production in polyculture system was 7.4 t/ha/120 days. The production of *tilapia* and *shing* in monoculture system was 9.9 t/ha/120 days and 2.0 t/ha/120 days, respectively. Overall yield of *tilapia* was significantly higher ($p<0.05$) than that of polyculture and monoculture of *shing*. The result indicated on the basis of benefit-cost-ratio (BCR) that gross margin was significantly higher ($p<0.05$) in *tilapia* monoculture than that in polyculture and monoculture of *shing*.

Keywords: ditch-dyke, low lying areas, livelihood, integrated aquaculture

1. Introduction

The pond-dike system was first applied in the flood-prone low-lying areas of the Pearl River delta region of South China (Ruddle and Zhong, 1988; Zhong *et al.*,1993). The system contains two interrelated systems of dike and pond; the dike is the land ecosystem for the growth of crop whereas, the pond is the water ecosystem, consisting of fish and aquatic plants. In this system, ponds are excavated and the dug-out soils used to raise the level of the low-lying ground surrounding the ponds, thus forming the dikes. The ratio of land to water in the system is an important consideration because it affects the energy flow (nutrients) between the two components. The typical ratio adopted by the farmers is 50% dike to 50% pond or 40% dike to 60% pond (Lo, 1996). Fish are reared in the ponds and crops are grown on the dikes. Fish feces and crop residues accumulated at the bottom of the pond are used as organic fertilizer for the crops growing on the dikes. In this way, wastes generated in each

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system are disposed of efficiently by generating nutrients to sustain production in another component of the system (Korn, 1996). The input and output of material and energy in the pond-dike system are basically balanced (Ruddleand Chung, 1988;Korn, 1996).

Promotion of integrated agriculture-aquaculture (IAA) has become central to aquaculture extension efforts to resource poor farmers in Bangladesh. IAA systems including rice–fish (Haroon *et al.*, 1992; Ali *et al.*, 1999; Bhuiyan, 1999), poultry–fish (Ali *et al.*, 1995; Samsuzzaman, 2002; Little and Edwards, 2003), duck-cum-fish (Ali *et al.*, 1995) and duck–weed–fish based systems (Azim and Wahab, 1998) have been promoted. In Bangladesh, vegetable production on pond-dike yields better economic benefits than fish culture alone (Shamsuddoha and Janssen, 2003) and may be more attractive to poorer households. Vegetable production on dikes provides leaves for use as feed for grass carp within the polyculture systems (Shamsuddoha and Janssen, 2003). Such forms of IAA have a high potential for improving livelihoods of poor smallholder households (Talukder *et al.*, 2001; HKI, 2003).

Majority of the people living in low lying areas in greater district of Jhalakati and its adjacent areas in the southern part of Bangladesh are in low productivity trap. Crop production in these low lying areas is neither feasible nor profitable because about 10.3% lands remain under water for 6-8 months. As a result, only one crop is grown during drought season and land remains fallow during the rainy season. With the given situation, adaptation methods need to be developed for making such unproductive land into highly productive one at affordable cost. The application of pond-dike system in flood-prone low-lying areas in Bangladesh may be a high potential to improve livelihoods of poor households. The purpose of this study is to find out economically feasible production systems of suitable fish species in pond-dike system for improving sustainable livelihood of poorer farmers living around the low lying areas.

2. Materials and Methods

2.1 Farmer selection

A total of 30 farmers from Jhalokati Sadar and Rajapur upazilla of Jhalakati district were randomly selected. The information on the farm size, land-use patterns, managements and socio-economic aspects of the farmers were collected through the interview. Data were also collected from local administrative units viz., Upazila Agriculture Office (UAO) and Upazila Fisheries Office (UFO). Eight interested farmers each having approximately 1590 m^2 of land for pond-dike system were selected from Jhalakati Sadar and Rajapur upazila of Jhalakati district (Fig. 1).

2.2 Construction of pond-dike system

The success of integrated pond-dike system (IPDS) relies on the proper use of the following three components (i) construction of pond-dike system, (ii) crop cultivation on the dike, and (iii) pond fish culture in the pond (Lo, 1996). Therefore, the first component was to construct pond-dike system in the low-lying areas of Jhalokati district for integrated crop-fish cultivation. The low lying area of Jhalokati district was generally inundated under water. Therefore, it was not possible to develop pond-dike system during inundated condition during May to December. The pond-dike systems were developed in January when the land became dry.

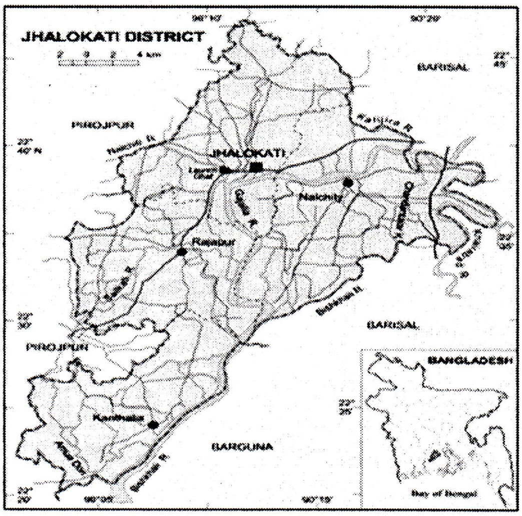

Fig. 1. Map of the study area.

Pond-dike system is a series of small ponds with 2-5 internal dikes (Fig. 2). A small passage between two neighbouring ponds was kept through which fish can move from one pond to another. The height of dike above the land was 1-1.5 m and depth of pond from the land was 1.5 m and a water level of 1.5-2.0 m was maintained for fish culture (Zhong *et al.*, 1993). The inside of the slope was 1:1.5 and the outside of the slope was about 1:1. The pond was filled with water from the nearby tidal canals. The size of the pond-dike system and pond: dike ratio is given in Table 1.

Table 1. Size of the pond-dike system and pond: dike ratio.

Pond-dike system	Total area of land (m^2)	Dike area (m^2)	Pond area (m^2)	Pond: Dike Ratio
1	1376	648	729	1:1.1
2	1619	810	810	1:1.0
3	1417	688	729	1:1.1
4	1417	688	729	1:1.1
5	1579	729	850	1:1.2
6	1457	688	769	1:1.1
7	1376	648	729	1:1.1
8	1295	648	648	1:1.0

2.3 Fish culture

The purpose of the study was to evaluate the growth performance and production of different fish species in monoculture (*tilapia* and *shing*) and polyculture (rohu, *catla*, silver carp, *pangus*, and grass carp) systems using commercial fish feeds to determine the profitable fish culture technique in pond-dike system in this area. The experiment has been conducted in eight earthen ponds of pond-dike system at Jalokathi from 09 June 2012 to 08 October 2012. The intra-connected passage between neighbouring ditches at each pond-dike system had been blocked up for introducing monoculture and poly-culture system of different fish species in each farmer pond-dike system.

2.3.1 Pond preparation

The ponds were filled with water up to a level of approximately 1.2 m. The ponds were treated with lime at the rate of 0.03kg/ m^2 and with fertilizer of urea and TSP at a rate of 0.003 and 0.004 kg/ m^2, respectively. When water turned deep green, fish were stocked at each pond.

2.3.2 Stocking and feeding

The stocking rate of different fish culture systems is shown in Table 2. The fish seeds were collected from Bismillah Hatchery Limited, Jessore for stocking in farmer's ponds at Jalokathi. The fish seeds were transported to the farm in oxygenated polythene bags covered by jute bags. The fries were released to the culture ponds after sufficient acclimatization. At the time of stocking, 20 fish of each species were weighed in order to record the initial average weight (Table 2). Locally available commercially pellet feed (Mega Fish Feed, Produced by Spectra Hexa Feeds Limited) was selected for the experiment. The proximate compositions of pellet feeds are given in Table 3. The feeding strategy of pellet feed for different sizes fish are shown in Table 4. Moreover, these ponds were organically fertilized weekly with cowdung manure at a rate of 2500 kg/ha to enhance primary productivity. The stocked fish was sampled fortnightly with the help of cast net from each pond. Ten fish were sampled from each pond. The fish weight was recorded to observe their growth performance. After obtaining the required data, fish were released back into their respective pond.

Table 2. Stocking rateand sizes of different fish species.

Fish species with culture system	Pond area (m^2)	Stocking density (nos./40.5 m^2)	Average fish weight at stocking (g)
Monoculture			
Tilapia	2025	200	2.7
Shing	1990	300	2.4
Polyculture	1975		
Silver carp		11	9.3
Catla		4	9.0
Rui		8	9.5
Grass carp		5	5.3
Pangus		22	4.5

Table 3. Proximate composition of different types of pellet feed.

Constituents	Amount (%)	
	Starter	Grower
Protein	30	28
Lipid	3	3
Ash	10	10

2.3.3 Fish growth and water quality parameter

Specific growth rate (SGR) and Average Daily Growth (ADG) were calculated using the following formula:

Hydrological characteristics of ponds, such as water temperature, pH, and dissolved oxygen were determined. At the end of the culture period, the fish from the ponds were completely harvested and the data were recorded.

2.4 Data analysis: In order to determine statistically significant differences among

Table 4. Feeding strategy of pellet feed for different sizes fish.

Average fish wt (g)	Types of supplied feed	Feeding rate (% body wt)	Feeding frequency/day
3-10	Starter 101	10-7	4 times
10-25	Starter 101	7-6	4 times
26-75	Grower 102	5.8-4	4 times
76-200	Grower 102	4-2.25	4 times
200- before selling	Grower 102	2.5 -	4 times

different treatment means, experimental values were compared using a General Linear Model (GLM). The significance level was set at p<0.05.

3. Results and Discussion

1.1 Water quality parameter

The growth performance of aquatic organisms depends on the water quality of a water body. The mean values of water quality parameter of monoculture and polyculture systems during the study period have been presented in Table 5. The water temperature, dissolved oxygen (DO) and pH of the experimental ponds did not show any significant difference (p>0.05) between monoculture and polyculture systems. Temperature is an important water quality parameter found to vary from 24.29 °C to 24.67 °C in monoculture and polyculture ponds. Wahab *et al.* (1995) recorded the water temperature from 27.2 °C to 32.4 °C in their experimental ponds. The results of this study shows consistency with the previous study. Rahman (1992) reported that the range of pH of a suitable water body for fish culture would be from 6.5 to 8.5. pH values in monoculture and polyculture systems of this study varied from 7.76 to

Table 5. Water quality parameters of monoculture and polyculture system.

Parameters	Monoculture (Tilapia)	Monoculture (Shing)	Polyculture
Temperature (^{0}C)	24.29±0.06	23.89±0.26	24.67±0.03
pH	7.96±0.33	7.36±0.03	7.76±0.63
DO (mg/L)	5.04±0.09	4.92±0.15	5.3±0.16

Table 6. Fish growth parameter of different fish species in monoculture and polyculture systems.

Fish species with culture system	Fish growth parameter	
	ADG (g/day)	SGR (%)
Monoculture		
Tilapia	1.98±0.23	3.74±0.10
Shing	0.59±0.18	2.83±0.28
Polyculture		
Silver carp	4.92±1.44	3.45±0.23
Catla	5.15±1.11	3.52±0.17
Rui	4.33±0.24	3.35±0.05
Grass carp	2.49±0.79	3.35±0.27
Pangus	5.02±1.55	4.06±0.24

Table 7. ANOVA for key variables.

Parameter	Unit	Fish culture techniques		
		Monoculture (Tilapia)	Polyculture	Monoculture (Shing)
Yield	(t/ha/120 days)	9.9[a]	7.4[b]	2.0[c]
Input cost	(BDT/ha/120 days)	719738.0 [a]	561224.0 [b]	530432.5 [b]
Gross income	(BDT/ha/120 days)	1211288.0 [a]	771408.0 [b]	720416.7 [b]
Gross margin	(BDT/ha/120 days)	491550.0 [a]	210185.0 [b]	189984.2 [b]
Benefit Cost Ratio (BCR)		0.68 [a]	0.37 [b]	0.35 [b]

Mean values followed by different superscript letters in each row indicate significantly different ($p<0.05$) based on GLM (General Linear Model)

7.96, indicating the suitable condition for fish culture. The suitable range of dissolved oxygen for fish culture should be from 5.0 mg/L to 8.0 mg/L (DoF, 1996). The concentration of dissolved oxygen in monoculture and polyculture ponds ranged from 5.03 mg/L to 5.4 mg/L, showing consistency with the recommended range.

1.2 Fish production

The growth rate of different fishes is recorded at 15 days interval. The mean final weight of *rohu, catla*, silver carp, *pangus*, and grass carp in polyculture system were 529 ±28.9g, 627±32.5g, 600±45.5g, 607 ±95.5g, and 303 ±63.5g, respectively. The mean final weight of *shing* and *tilapia* in monoculture system were 72.73±21.0 g and 240±27.8g, respectively (Fig. 4 and 5). The fortnightly growth of different fish species taken from 09 June to 08 October 2012 was exponential (Fig. 3).

The average daily growth (ADG) and specific growth rate (SGR% per day) were calculated for evaluating growth performance of different fish species in monoculture and polyculture systems (Table 6). The ADG were approximately

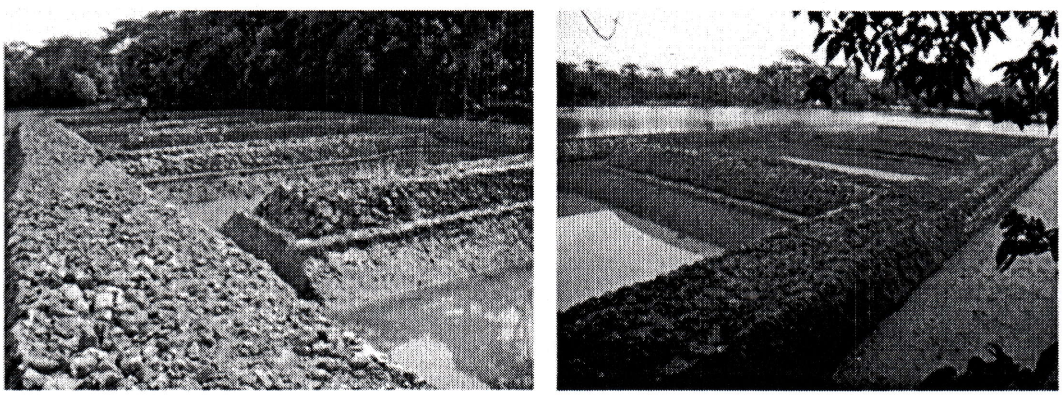

Fig. 2. Pond-dike system constructed in low-lying area of Jalokathi.

two times for *catla*, silver carp, and *pangus* than that of grass carp in polyculture system. In contrast, the ADG were approximately four times for *tilapia* compared to that of *shing* in monoculture system. The SGR was approximately 3.5 for fish species of polyculture system. In contrast, the SGR was 2.83 for *shing* and 3.74 for *tilapia* in monoculture system. SGRs can be greater than 3 at first feeding, while fish over 1.0 kg have average values of 1. This is because smaller fishes are capable of eating a much greater percentage of their body weight per day.

The production of *tilapia* and *shing* was 9.9 t/ha/120 days and 2.0 t/ha/120 days, respectively. The fish production in polyculture system was 7.4 t/ha/120 days. Hasan *et al.* (2010) found the ADG (g/day) and SGR (% per day) of 1.38 and 3.85 for

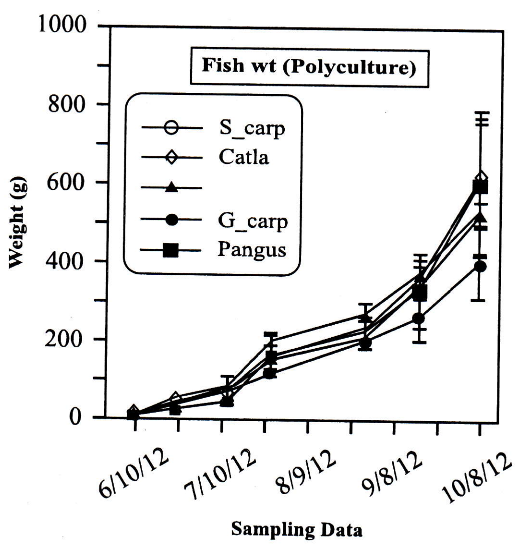

Fig. 3. Fortnightly average growths of different fish species during the experimental period from 09 June to 08 October 2012.

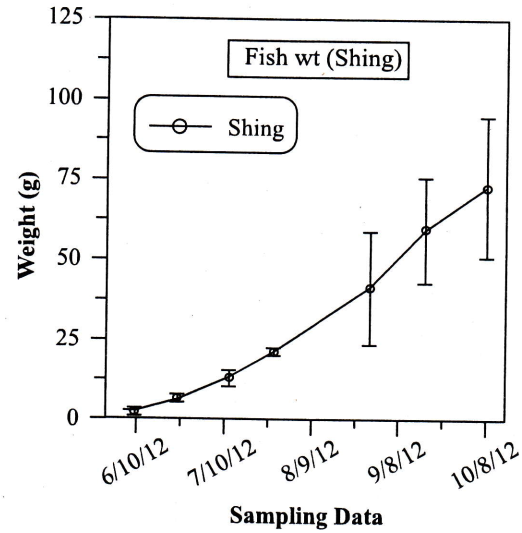

Fig. 4. Fortnightly average growth of Shing during the experimental period from 09 June to 08 October 2012.

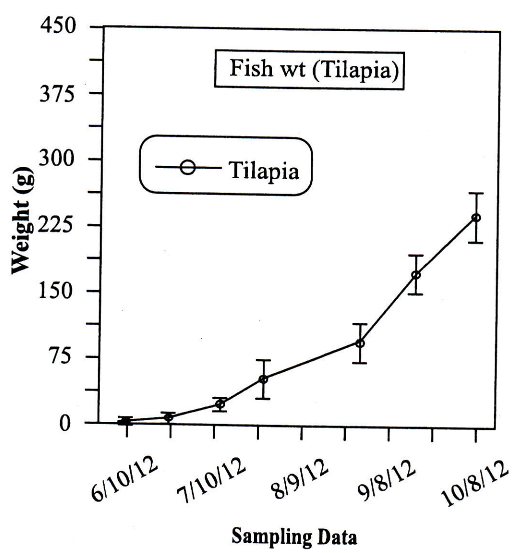

Fig. 5. Fortnightly average growth of Tilapia during the experimental period from 09 June to 08 October 2012.

tilapia with a production of 6.9 t/ha/120 days at stocking density of 5 nos./m^2. In contrast, Khan et al. (2003) found the ADG (g/day) and SGR (% per day) of 0.4 and 3.54 in *shing* with a production of 3.2 t/ha/120 days at stocking density of 8 nos./m^2. Ahmed (2010) found the SGR (% per day) of 2.5 in *shing*. Results of the present study showed consistency with the previous studies.

3.3 Economics

Input costs were significantly higher ($p<0.05$) in monoculture of *tilapia* compared to polyculture and monoculture of *shing* (Table 7). Overall yield of *tilapia* was significantly higher ($p<0.05$) than polyculture and monoculture of *shing*. In monoculture of *tilapia*, gross income was higher ($p<0.05$) compared to that of polyculture and monoculture of *shing*. On the basis of benefit-cost-ratio (BCR), gross margins were significantly higher ($p<0.05$) in monoculture of *tilapia* than that of polyculture and monoculture of *shing*. The result indicated that the farmer's income would be more than double for *tilapia* culture instead of polycultureand monoculture of *shing*.

4. Conclusion

Utilizing a pond-dike system in the low lying area is an eco-friendly approach. If pond-dike system is popularized for use in the low lying areas of southern part of Bangladesh, it would increase the incomes of farmers living around the low lying area. In our opinion, the pond-dike system could be a new ecological engineering mode for poorer farmers in low lying areas of Bangladesh.

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