Polyculture Performance of Indigenous and Exotic Fish Species in Pond

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DECLARATION

These results submitted in this project thesis are entirely the candidate's own investigations and no part of the results have been accepted for any degree, nor it is being concurrently submitted for any degree

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Ripon Kanti Ghosh

DEDICATED TO

MY BELOVED PARENTS

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ABSTRACT

The study was conducted to determine the polyculture performance of both indigenous and exotic fish species at Kandua Village in Madaripur district over a period of 6 months from 31 August 2001 to 1 March 2002. The combination of exotic fish species with selected indigenous fish species designated as treatment T1, treatment T2 and treatment T3 in nine ponds. Treatment T1 comprised of indigenous species rohu (*Labeo rohita*) catla (*Catla catla*) mrigal (*Cirrhinus mrigala*) and exotic species silver carp (*Hypopthalmichthys molitrix*) and grass carp (*Ctenòpharngodon idella*). Treatment T2 comprised of indigenous species rohu (*Labeo rohita*) catla (*Catla catla*) mrigal (*Cirrhinus mrigala*) and exotic species silver carp (*Hypopthalmichthys molitrix*) and thai pangus (*Pangasius sutchi*) and in Treatment T3 the indigenous species was rohu (*Labeo rohita)* catla (*Catla catla*) mrigal (*Cirrhinus mrigala*) and the exotic species grass carp (*Hypopthalmichthys molitrix)* and thai pangus (*Pangasius sutchi*). The surface area of each pond was 80-sq. meter with the depth ranged from 0.75-1.0 meter. The stocking density was 11250 fingerlings/ha in all Treatments. The ponds were cleaned, lined and fertilized prior to stocking. The fishes were fed rice bran and mustard oil cake at 4% of the body weight. The production of fishes showed the positive relationship with temperature dissolved oxygen and pH. The initial weight of fishes showed the highly significant relation with its final weight in all treatments, but in treatment T2 the relation (r=0.989) was found to better than the other two. T1 showed better performance in terms of both gross (1965.68 kg/ha) and net (1806.03 kg/ha) production, survival rate (80.68%) and benefit cost ratio (2.33) whereas T2 showed better performance interms of growth and T3 showed better relation between survival rate and net production (r= 0.990). Finally it may concluded that T1 composition is the better composition for polyculture in pond.

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Chapter-One

INTRODUCTION

1.0 INTRODUCTION

Bangladesh have extensive areas of freshwater including ponds, lakes, canals, haors, baors, rivers floodplains and marine waters that covered two-thirds (20,91,494 hacters) of the total area of country. The fisheries resources of these areas represent one of the most valuable assets of our country. Total freshwater resources of our country are 52.82 lakh ha. Whereas rivers, and estuaries are 10.31 lakh ha.; haors and beels 1.14 lakh ha., ponds and ditches 2.15 lakh ha.; baors 0.0055 lakh ha.; floodplains 28.33 lakh ha. and coastal shrimp farm areas 1.41 lakh ha. Moreover, Bangladesh have 166.07 lakh sq. km of marine water bodies (DOF, 2001).

The water resources were very rich in past, but the production of fish has failed to keep pace with the population size that is increasing in geometric rate. Over 130 millions of people of the country depend on this sector for their animal protein and about 12 millions of people are directly or indirectly depend on fisheries sector for their livelihood. The competent fisheries manpower can play an ever important role to bring a change in fisheries production and profitability that have such a crucial place in the national economy, nutrition and employment.

In Bangladesh, it is second to agriculture in the overall national economy that contributes 5.3% to the national GDP. Fishes contribute 63% of an animal protein to our daily diet (DOF, 2001). Per capita per day fish consumption which was 32 g in mid sixties declined to the level of 20 g in mid eighties (FAO/UNDP 1985). Fish production has increased significantly over the last few years. During 2000-2001 total fish production in Bangladesh was 20.01 lakh MT. This fish production level reflects per capita per day availability of 25 g of fish whereas the minimum requirement is about 38 g (DOF, 2001).. To overcome this problem it is necessary to supply protein rich diet to the people. This can only be achieved through culture of fish in our unutilized and derelict inland water bodies. There is no alternative way to escape from this dilemma without developing aquaculture.

Polyculture or composite culture is the system in which fast growing compatible species of different proportions is in the same pond (Jhingran, 1975). The basic principles of the composite culture; species of different feeding habits are cultured in the same pond to avoid food competition and best utilization of natural foods of different habitats without any harm to each other. It is a fact that, polyculture may produce an expected result if the fish with different feeding habits are stocked in proper ratios and combinations (Halver, 1984). This principle based on the assumption that fish growth is an expression of their reaction to, among their things, the sources of natural food in the environment (Shepherd and Bromage, 1992).

Selection of fish species plays an important role for any cultural practices. The better utilization of different strata and zones of a pond three or more species must be stocked. In our country suitable or common combinations of fish for composite culture is rohu (*Labeo rohita*), catla (*Catla catla*), and mrigal (*Cirrhina mrigala*). Sometimes calbasu (*Labeo calbasu*) has been included in the polyculture. In recent years, some exotic fish species have drawn an attention to farmer for their better growth performance. Fish culturist introduced several exotic fishes in order to obtain more production at minimum cost and the shortest possible period. They are now being cultured combindly with the local carps. Among those, silver carp (*Hypophthalmichthys molitrix*), grass carp (*Ctenopharyngodon idella*), common carp (*Cyprinus carpio*), raj punti (*Puntius gonionotus*) are the most popular species. Now a days, pangus (*Pangasius sutchi*) has also been introduced in freshwater ponds.

It is assumed that, exotic species may compete for food and space with the indigenous species. As a result, ecological balance may break down. So, prior to introduce as exotic species; it is necessary to know their food and feeding habits, niches and habits etc.

Considering the enormous importance of seasonal ponds as a sources of income and family nutrition, the present study was conducted to find out a suitable stocking model or option that could be adopted by the fish farmers to drive maximum benefit from the ponds. Development of production technologies can not be taken as a determinant for acceptance of the same to the fish farmers. Some other factors might be considered of which the economic profitability and relative advantage of the production technology are the most important ones (Khaleque *et al.*, 1998). Shang and Costa-Pierce (1983) emphasized the importance of economic analysis of any culture practices as it provides a basis not only in the decision making of the individual farmer but also in the information of aquaculture policies.

The study was carried out to investigate the production performance and the combination of both indigenous and exotic fish species in pond polyculture system. This study was undertaken to the following objectives:

1. To study the effect of physico-chemical factors of water on the production of fish.
2. To know the effect of stocking density on growth, survival and production.
3. To determine suitable species combination of both indigenous and exotic fishes.
4. To analyze the economic performance of the selected stocking model in terms of marginal rate of return.

Chapter-Two

REVIEW OF LITERATURES

2.0 REVIEW OF LITERATURES

2.1 Physico-Chemical Parameters

Different environmental factors that determine the characters of water have great importance upon the growth, maturity, survivability and the development of fish. The relationships between the fish and their aquatic environment are not isolated phenomenon but changes of one may reflect on effect on the other. The existence, growth, production and survivability of aquatic life are mediated through a chain of interacting physical and chemical parameters of water. Aquatic organisms thrive well under congenial physico-chemical conditions but under stressful conditions they are interrupted. The relevant literatures about physico-chemical parameters are reviewed below:

Alam *et al.* (1985) found that the growth rate of silver carp was directly related to the limnological parameters of the pond, which were favorable for fish life.

Ali *et al.* (1982) observed temperature range of 20.5-36.5 ^{0}C, pH range of 7.5-9.5, dissolved oxygen 7.2-10.5 mg/L, throughout the period of investigation in a fresh water ponds which are favorable for pond fish culture.

Banerjea (1967) stated that ponds were unproductive when oxygen ranged from 3.0 to 5.0 ppm and also reported 7.0 ppm of dissolved oxygen of water body is good for productivity.

Bhuyan (1970) is of opinion that pH above 7.0 is suitable for fish production and dissolved oxygen from 5.0 to 7.0 mg/L is required for high production.

Dewan (1973) investigated into the ecology in a Mymensingh lake (Bangladesh Agricultural University Campus). He observed higher oxygen concentration during winter and lower oxygen concentration during monsoon. He pointed out that the dissolved oxygen bears an inverse relationship with temperature and free carbon-di-oxide; a direct relationship with pH and total alkalinity.

Dewan *et al.* (1991) recorded the ranges of temperature 30.2-34 ^{0}C, pH 6.6-8.8 and dissolved oxygen 2.2-8.8 ppm from a lake situated in Bangladesh Agricultural University Campus, Mymensingh.

Durve and Bal (1961) reported the lowest temperature of water during winter and the highest temperature during summer in their study in the Kelwa backwater and adjoining sea near Bombay.

George (1961) found that dissolved oxygen varied from 4.5 ppm to 9.9 ppm. He noted the highest value at 5.30 PM and lowest at 5.30 AM and stated that high O_2 content were associated with high rate of photosynthesis.

Goolish and Adelman (1984) recorded maximum growth rate at 30 ^{0}C temperature of juvenile common carp. They also observed that the temperature of natural inland waters in the temperate regions generally varies between 0 ^{0}C and 30 ^{0}C, the maximum values occurring particularly in shallow waters in summer and the minimum exceptionally fall below zero in winter.

Islam *et al.* (1978) observed minimum values of dissolved oxygen during summer and maximum in winter. They observed water temperature was closely related with air temperature.

Kohinoor *et al.* (1993) compared the growth performances of *Puntius gonionotus* with and without using fertilizer and rice bran. They used urea, TSP and rice bran at 8 kg/ha, 16 kg/ha and 750 kg/ha, respectively and recorded a yield of 2,384.26 kg/ha/6 months. Production of Rajputi *(Puntius gonionotus) was* 2,129.72 kg/ha/6 months under condition of supplemental feeding with rice bran.

Lakshminarayana (1965) in his study on the physico-chemical characteristics observed the higher values of dissolved oxygen throughout most of winter seasons. He stated that the low values of pH during rainy due to the changes in the levels of carbon-de-oxide and carbonates.

Lakshmanan *et al.* (1967) studied on survival and growth of cultivated fishes at the Government fish farms in five districts of Assam. They observed the highest temperature on all the ponds during the months July to August and the lowest during the months of December to January.

Macan and Maudsley (1966) concluded that the body temperature of water vary considerably in different months. They also observed that water temperature was influenced by its size.

Mascid *et al.* (1998) investigated the water quality and plankton production in derelict, traditional and semi-intensive fishponds in Karimgonj Thana under Kishoregonj district. They noted a significant variation in the value of dissolved oxygen (4.3-8.1 ppm), pH (5.6-7.8), and total alkalinity (15-145 ppm) among three categories of the ponds. Fluctuation of physico-chemical qualities of water was more pronounced in semi-intensive fishponds. Both phytoplankton and zooplankton population were higher in semi-intensively managed ponds which received regular supply of urea, triple super phosphate and compost. No fish kill was observed in the manure-loaded ponds.

Martyshev (1983) stated from the study of the chemical parameters characterizing the suitability of water for carp and trout farms; he observed more than 4 ppm dissolved oxygen and pH 7.0 is optimum values for carps.

Michael (1969) reported that the pH ranging between 7.3 and 8.4 was the most suitable for fish culture. The amount of dissolved gases at any given time was found to be associated with biological activities in water. He further observed variations in total quantity of plankton affected the fish growth and production.

Mirza *et al.* (1978) studied the physico-chemical characteristics of the river Old Brahmaputra at Mymensingh for a period of one year. The physical factor temperature was found to play important role in aquatic medium and the value of dissolved oxygen was positively correlated with photosynthetic activities of the phytoplankton population.

Oppenheimer *et al.* (1978) observed a declining trend of dissolved oxygen, pH, alkalinity and hardness during monsoon in three ponds in Dhaka city and pointed out that the horizontal bottoms of the ponds were richer in nutrients that the sloping sides.

Pahwa and Mehrotra (1966) observed the maximum values of dissolved oxygen during winter and minimum values of the same during July and August.

Rahman *et al.* (1982) made a study on the physico-chemical conditions of four selected ponds and the river Old Brahmaputra. The ranges of water temperature, dissolved oxygen, free carbon-de-oxide, pH, phosphate-phosphorus and nitrate nitrogen were 26.06-31.97 ^{0}C, 6-9.2 mg/L, 0-3 mg/L, 7.2-7.6, 0.028-0.173 mg/L and 0.074-0.304 mg/L respectively in the river Old Brahmaputra.

Singh and Singh (1975) concluded that in organically manured ponds dissolved oxygen, pH and total alkalinity remained in the range of 3.0-8.5 mg/L, 6.0–7.8 and 30–125 mg/L which were they considered to be favorable for the growth and survival of major carps and related species of fish.

Verma (1969) made an investigation on a tropical impoundment in India. He observed the highest values of pH during summer and lowest values of the same during winter. Heavy influx of water decreases the pH values.

Wahab *et al.* (1995) recorded a low content of dissolved oxygen ranging between 2.0-7.2 mg/L during the experiment in the pond of Bangladesh Agricultural University Campus, Mymensingh.

Zafar (1964) studied the physical and chemical parameters of certain fishponds at Hyderabad in India. He recorded pH (7.8-8.4), phosphate (0.0028-0.0044 mg/L), dissolved oxygen (6.16 - 8.12 mg/L) and bicarbonate alkalinity (0.05-4.44 mg/L).

2.2 Growth, Survival and Production of Fishes

In polyculture, the growth, survivability and production of fish depend upon the species combination, stocking density, feeding, fertilization etc. a vast number of literatures exists in the biology and culture of indigenous and exotic fish species. The literatures are reviewed below which is related with the present study.

Ariza and Romero (1993) stated that silver carp has higher growth rate than other species. In four months of culture, weights of 683 g for silver carp were obtained.

Blackburn and Sutton (1971) reported that both Hydrilla and southern Naiad enhanced the growth of grass carp fingerlings than commercial feed. Fingerlings fed with hybrid napier grass grew three times faster than those fed hydrilia and five times faster than those given coontail. Food conversion values were 27.0, 97.4 and 128.4 respectively. *Ctenopharyngodon idella* of 1 kg or more eat whole plants of water hyacinth, but small individuals can only utilize the roots. Growth rates of 1.0-1.2 kg fish range from 1.4-8.8 g/d, and for 0.1-kg specimens vary from 0.7 to 1.7 g/d.

Buck *et al.* (1978) evaluated the effect of swine manure on the growth of fish in polyculture with Chinese carp. Daily manure application from 39-85 swine/ha produced maximum yield of 4585 kg/ha as compared to 780 kg/ha in control pond. Though total mortality occurred in one pond due to oxygen depletion but in most cases water quality was fairly good.

Burke *et al.* (1986) assessed the impact of bighead and silver carp on the plankton population of the channel catfish ponds in Alabama, USA. Their observation lead to the conclusion that a reduction in the zooplankton was brought out by both the species.

Chaudhuri *et al.* (1975) conducted a comprehensive study on culture of the Indian major carp, *Catla catla, Labeo rohita and Cirrhna mrigala* together with the Chinese carp, grass carp and the Indonesian strain of common carp *(Cyprinus carpio)* in experimental ponds, In the first year, production varied from 3,889 to 5,600 kg/ha/yr. and this rose to an average of 8,200 kg/ha/yr. with a minimum of 9,389 kg/yr. in the second year. The important management tools schedule were increased stocking densities, greater use of feed and fertilizers, and provision of more weeds for grass carp.

Chaudhuri *et al.* (1978) reported fish production by application of composite fish culture technology in ponds, with a high stocking density of 13320 fingerlings per ha. The ponds recorded average gross and net productions of 7633.5 and 7444.8 kg/ha/yr. which was about 7 times the normal production of around 1000 kg/ha/yr. reported by the ordinary fish farmers.

Davis *et al.* (1984) conducted fish culture trials in managed farmer's ponds with different feeding and stocking regimes. The species were employed, silver carp, catla, rohu, mrigal, common carp and grass carp while the feed were rice bran, mustard oil cake and rice bran + mustard oil cake and compost. Average fish production from 16 ponds was 2830 kg/ha with a range from 1890 to 3820 kg over the 12 months study period.

Dewan *et al.* (1991) stated that least dietary overlap was observed between catla and rohu and between silver carp and bighead carp, whilst highest values (i.e. greatest overlap) were for catla-silver carp and catla-bighead carp in the pond of Bangladesh.

Dey *et al.* (1979) suggested that the competition between silver carp and rohu was possibly not a serious one. Although, the feeding habits of silver carp (surface feeder) and rohu (column feeder) are somewhat different and the two are considered as quite compatible species and recommended in composite fish culture.

Dunseth and Smitlierman (1977) conducted an experiment to find out the effectiveness of polyculture using carp and bighead carp in catfish grow-out ponds. They noted a slight reduction in catfish yield but the total fish production increased from 2371 lbs/acre/yr. in monoculture to 4118 lbs/acre/yr. in polyculture.

Gosli *et al.* (1973) investigated the growth and cultural prospects of silver carp in some sewage fed ponds in India. The average weight attained by the species was about 1 kg in 5 months.

Gupta *et al.* (1990) showed that the total production of Indian and exotic carps were 4917 kg/ha/yr. with supplementary feed. The ponds with supplementary feed i.e. rice bran and mustard oil cake (1:1) was provided at the rate of 3 % of body weight.

Halver (1984) stated that polyculture may produce an expected result if the fish with different feeding habits are stocked in proper ratios and combinations.

Hepher and Milstein (1989) studied the interaction between bottom feeding fish (common carp and hybrid tilapia) and a filter feeder (silver carp) in polyculture in fertilized ponds with no supplementary feeding. The silver carps were stocked at two densities; 1,300 and 2,600/ha. Combined yield of all species in the polyculture was highest at the density of 1,300 silver carp/ha (2116 kg/ha in 156 days). At 2,600 silver carp/ha (1690 kg/ha in 156 days) inhibition of growth rate of silver carp itself reduced total yield as compared with the lower density.

Hepher *et al.* (1989) reported that the increasing density of silver carp reduced proportionately their growth rate, due to the limited amount of food. Above a density of about 1000/ha, silver carp inhibit the growth rate of common carp and tilapia.

Hossain *et al.* (1994) under took a study on composite fish culture using silver carp (*Hypophthalmichthys molitrix*) along with Indian major carp (*Catla catla, Labeo rohita and Cirrhinus mrigala*) and only Indian major carps in another combination II (Catla: rohu: mrigal = 50:30:20). Fingerling were stocked at 7,410 kg/ha and the ponds were fertilized with cow-dung, Murate of Potash (MP) and Triple Super phosphate (TSP) at one month interval in equal proportion at the rate of 82.3 kg/ha and fishes were also production in combination I (3,062 kg/ha) was higher than the total production in combination 11 (2,836 kg/ha) resulting 13.76% higher net profit.

Janeeck *et al.* (1984) studied an experiment on "Experimental rearing of stock carp in polyculture with silver carp and grass crap". He reported that the yield of silver carp was the dominant among the total production.

Jauncey and Matty (1979) conducted a research on growth of mirror carp. They showed that the mirror carp (*Cyprinus carpio*) has excellent growth rates for culture purposes. Specific growth rate (SGR) can reach 3.5, if an average SGR of 3 were attained a fish would grow from 1 g to 1 kg in 33 weeks. With carp an SGR of 5 or 6 might be possible, they also showed that carp would also tolerate high stocking density, up to about 225 kg of fish per cubic meter. It would also tolerate a wide range of temperature, up to 40^0C and rapid temperature fluctuations.

Jhingran (1976) reported that culture of silver carps along with Indian major carps has recently been developed in India as composite fish culture. In this method, the production as high as 3000-5800 kg/ha per 6 months and 7000-9000 kg/ha per year in different parts of the country has been achieved.

Jhingran (1991) stated that the growth of exotic carps being fast, these fish attain marketable sizes much earlier and it is therefore, suggested that they should be harvested at the earliest to enable multiple cropping for higher rates of production.

Kader *et al.* (1989) conducted a polyculture experiment with exotic silver carp in different stocking combinations. Silver carp and catla when stocked in 2:1 ratio gave higher yield. A severe food competition between these two species was clearly noticed.

Khan and Jhingran (1975) stated that in small ponds artificial feeding can double or triple the production, Artificial feeding also modify the soil and water quality of the unfertile ponds. The artificial feed acts as pond Fertilizer as well.

Lakshmanan *et al.* (1969) reported the results of their studies on rearing of carp fingerlings. Fifteen day old fry of *Catla catla, Labeo rohita, Cirrhina mrigala and Cyprinus carpio* var. were reared in earthen ponds for 3 months at the densities of 62,500, 93,750 and 125,000 per hectare in the ratio of 3:4:1:2 respectively. The fingerlings were fed daily with a mixture of mustard oil cake and rice bran. The ponds were fertilized with nitrogenous and phosphate fertilizers. The growth rate of the fingerlings was fairly high except in catla and common carp. The average production rates under the three stocking densities ranged from 2002.28 to 3127.75 kg/ha/3 months.

Laksmanan *et al.* (1971) reported results of 8 field experiments on composite culture of fish using seven important cultivated species, Viz. *Catla catla, Labeo rohita, Cirrhinus mrigala, Hypophthalmichthys molitrix, Ctenopharyngodon idella, Cyptinus carpio var. communis and Labeo calbasu.* Fingerlings were stocked at densities of 4,450, 5,000 and 6,250/ha. The ponds were fertilized with organic and inorganic manures fortnightly and fishes were fed daily with a mixture of mustard oil cake and rice bran and grass carp with suitable aquatic weeds. Survival was generally high, averaging more than 80 per cent, which resulted in high rate of production ranging from 2,230 to 4,209 kg/ha/yr.

Ling (1977) reported that through polyculture a yield of 7287 kg/ha could be obtained from heavily fertilized ponds as against 424 kg/ha obtained from the ponds without fertilizer. In his experiment the ponds were stocked with the species of silver carp, bighead carp, grass carp, grey mullet common carp and sea perch.

Malecha *et al.* (1981) tested the feasibility of raising the freshwater prawn, *Macrobrachium rosenbergii* without supplemental feeding in a polyculture system with silver carp, bighead carp and grass carp and later with common carp in a ratio of 65:1:4:12 with a combined density of about 5500/ha. The production was averaged 2516 kg/ha (14.38 kg/ha/day) in the manured ponds and 613 kg/ha (6.06 kg/ha/day) in the effluent ponds.

Mathew *et al.* (1988) reported the result of a study on composite culture of six species viz., catla, rohu, mrigal, common carp, silver carp and grass carp. They stocked in proportion of 10:5:10:25:30:20 respectively at a density of 8000/ha, yielding a record production of 10183 kg/ha after rearing over a period of one year.

Michcwicz *et al.* (1972) observed that *C. idella* averaging 364 g grew from 1.3-5.7 g/d in out door concrete tanks and that 224 g specimens at higher density in indoor aquaria grew from 0.8-2.7 g/d.

Milstein (1990) stated that growth and yield of some fish species might be higher in polyculture than in monoculture due to positive interactions between species. When the concentrations of the different fish species are adequate in the polyculture pond, the growth rate of' plankton, macrophytes, benthos and nekton keep pace with the rate of consumption by the cultured fishes. In unbalanced conditions, the system is affected in different ways according to the food chain level where the imbalance occurs.

Moav *et al.* (1977) conducted polyculture trial with silver carp, grass carp and tilapia. The treatments differed in stocking densities, feeding and manuring levels. The most productive treatment was protein enriched feed which produced a biomass of 50 kg/ha/day. Two treatments (low and high stocking densities) fed exclusively with liquid cow manure produced an average yield of around 3 kg/ha/day. The yields of the treatments receiving high-protein pellets exceeded those of the treatments receiving grain pellets by 20 and 9.6 kg/ha/day, at high and low stocking densities, respectively.

Murty *et al.* (1978) conducted an experiment on composite fish culture through nitrogenous fertilization with and without supplemental feed. In their experiment three Indian carps and three exotic major carps were used at a stocking density of 5000 fingerling/ha. The yields of fish obtained though fertilization alone was 2275.37

kg/ha/yr., as against 3858.58 kg/ha/yr. obtained by using feed and fertilizers which indicate that combined use of feed and fertilizer have a significant effect on fish production.

Nandeesha and Rao (1989) reported that in polyculture grass carp largely feeds on macro vegetation and does not compete for food with other carps, while silver carp, a voracious feeder of phytoplankton and common carp which feeds on detritus compete to some extent for food with the Indian major carp.

Newton *et al.* (1978) compared the monoculture of channel catfish with that of polyculture using three species of Chinese carps and big mouth bass. It was observed that fish production from polyculture (1375 kg/ha) was far greater than that of monoculture (712 kg/ha).

Opuszyanski (1986) described the increased yield of polyculture as being a function of stocking density, age of fish, fertility of ponds and environmental temperature. He suggested that maximum economic yield should be, considered rather than maximum possible yield in case of polyculture practices.

Rahman (1996) evaluated the effects of stocking size of fingerlings on the growth, survival and production of carps under polyculture system in some perennial ponds in Bogra district. Rearing of 20, 50 and 100 g sized carp fingerlings at the rate of 7,410/ha gave an yield of 2618, 3712 and 4950 kg/ha/ 5 months respectively under semi-intensive system of pond management. Silver carp contributed to the bulk of the total fish production followed by mrigal and mirror carp. Stocking of larger fingerlings (100 + 5 g) gave higher fish production, reduced the culture period and accelerated the growth rate.

Saha *et al.* (1988) carried out a study to determine the growth performances of Rohu fry *(Labeo rohita)* in relation to different stocking densities in the earthen nurseries. The ponds were socked with four days old hatchings at 6.25, 7.50 and 8.75 trillion/ha. The ponds were fertilized with cattle dung at the rate of 10 tons/ha. Fry were fed daily with a mixture of finally powered mustard oil cake and rice bran. The average survival and growth of rohu at the above three densities were 73.94, 63.40, 57.17% and 32.0, 30.2 and 28.2 mm after 4 weeks.

Saha *et al.* (1989) observed the growth rate of silver carp *(Hypophtlialmichthys molitilx)* spawn under different types of fertilizers. The silver carp spawn were stocked at 0.6 million/ha and reared for 7 weeks. Pond treated with organic manure at 10 tons/ha gave higher production of zooplankton, while those treated with urea and TSP had increased number of phytoplankton. The growth rate of fry was faster during the five weeks of rearing in ponds treated with cattle dung. From 5 weeks onward growth rate was quicker in ponds receiving inorganic fertilizers indicating a change in feeding habits of silver carp. Maximum survival was achieved in inorganically fertilized ponds.

Sahabuddin *et al.* (1987ab) conducted a series of field experiments to determine the growth and survival rate of Indian and Chinese carp fingerling in ponds and organic fertilizer. Ponds fertilized with urea and TSP at 100 and 150 g/decimal/15 days were found to be optimal for the growth of carps.

Schroeder (1974, 1975) studied the effects of manuring on the production of natural fish food organisms and fish yield. He found that carps when stocked at the rate of 5,000 fish/ha grew 25-100 percent faster in manured pond than in unmanured ponds. He concluded that the increased production of zooplankton and chironomids were due to the result of increase in the production of bacteria and protozoa developing on the organic matter.

Schroeder and Hepher (1979) reported the results of their experiments on polyculture by applying cow manure. The rate of stocking density and manuring were 16,000 fish per ha and 5 g/sq./day (or about 100 kg dry matter of manure/ha/day) respectively. The fish production was 0.300-g/sq. m/day.

Singh and Singh (1975) reported that the weight gain by the fishes fed supplementary feed was 3 to 4 times more, than that of fish maintained in fertilized ponds. Among the 4 experimental ponds two were fertilized with cow-dung at the rate of 2500 kg/ha and other two were supplied with rice bran and groundnut oil cake as supplemental feed.

Singli *et al.* (1972) reported the results of a polyculture experiment using silver carp, grass carp and common carp together with major carps. By adjusting the stocking ratios of the fishes, they were able to achieve a yield of 6196 kg/ha/yr.

Spataru (1977) studied the gut content of silver carp and established tropic relationship with other species in the polyculture ponds. She observed that the fish filtered microseston, macrseston and trypton. Subsequent studies revealed that silver carp also consumed a significant amount of zooplankton. She described that rotifers and copepode naupli were rapidly decomposed in the gut fluid of silver carp and this was why zooplankton remained unrepresented in the stomach analysis.

Spataru (1977) tried to establish trophic relationship with silver carp and other species in the polyculture system. He observed that the fish filtered microseston, macroseston and trypton.

Spataru *et al.* (1980) conducted a research on qualitative and quantitative analyses carried out on the intestinal content of 408 carp of age collected from ponds manured with liquid cowshed manure, with or without addition of supplementary feed. They concluded that the natural food preferred by this species consists of the components of the zoobenthos, especially larvae and pupae of chironomids.

Stanley (1975) observed that the feeding of C *idella* stops at an oxygen level of 2-5 ppm with 61 mm, 2.7 g fingerlings fed duckweed *(Lenma mininw)* under intensive culture conditions, stocking density had no effect on growth rates until oxygen content fall below 4 mg/L, causing consumption to decrease 45%.

Sukumaran *et al.* (1968) studied the interaction between silver carp and catla in polyculture pond and noted that the silver carp adversely affected the growth rate of catla. However, they recorded better growth of silver carp in all the stocking combinations.

Sutton (1974) found the growth rates of small fish to be more sensitive to changes in temperature than those of large ones. A water temperature increase from 23-29^{0}C correlated with increased growth in 0.1 kg fish but not in 1.0 kg specimens. Otherwise the growth rate of fishes is slower during winter.

Tal and Ziv (1978a, 1978b) reported growth rates of 380-g fish to be 1.9 g/d with pelleted food and 6.1 g/d with duckweed. Fingerlings given duckweed grew 3.4 g/d with a conversion co-efficient of 3.7 in the second year.

Tang (1970), Sinha (1974) and Gupta (1990) have been shown that different species stocked in polyculture ponds occupy different niches with their complimentary feeding habits, fully utilizing all the natural food in the pond, thus increasing the total fish production from the pond.

Uddin *et al.* (1987) studied the effect of stocking ratios on the growth of fishes under carps polyculture system at a stocking density of 6,500 fingerlings/ha. After 10 months rearing, the maximum gross production was obtained at 3389 kg/ha with species ratio of catla. 30: silver carp 10: rohu 30: mrigal 20: grass carp 10. In their treatment the fishes were fed daily with a mixture of mustard oil cake and rice bran (3:2 ratio) at the rate of 3% body fertilizers (10 kg/ha/month) during the study.

Vesudevappa *et al.* (1989) conducted an experiment on "Silver carp-a boon to maximize fish yield in pond culture". The results of composite fish culture demonstrations conducted in Gangavathi taluk of Raichur district, Karnataka were presented. The fish fingerlings of catla, rohu, mrigal and silver carp were stocked in the ratio 2:3:3:2 at a stocking density of 12000/ha. The fish were harvested after a growth period of 9 months. The fish production was 2918 kg/ha. Silver carp showed the best growth followed respectively by catla, rohu and mrigal.

Wahab *et al.* (1994) reported the composite culture of Indian major carps viz., catla, rohu, mrigal, silver carp and common carp stocked at the rate of 15000/ha. The ponds were fertilized with cow-dung 366 kg/ha + Urea 9 kg/ha + TSP 7 kg/ha daily, cow-dung 2566 kg/ha + Urea 64 kg/ha + TSP 51 kg/ha weekly and cow-dung 5500 kg/ha + Urea 137 kg/ha + TSP 110 kg/ha fortnightly. The yield of different species of fish in different treatments was 1870.12 kg/ha, 1699.23 kg/ha, and 1622.33 kg/ha respectively.

Wohlfarth and Hulata (1987) reported that in China polyculture yields of 30-35 kg/ha/day have been obtained in different investigations. Yields as high as 50 kg/ha/day have been reached in standing water ponds using feed pellets with a 25% protein content, but with grains (sorghum) as supplemental feed, yields were lower than the maximum yields from intensive manuring alone.

Yashouv (1971) observed a positive interaction between silver carp and common carp. The silver carp enabled the common carp to exceed their previous limit of 391 kg/ha in monoculture. It was also found that the weight yield of silver carp, grown in polyculture with common carp, was higher than that of silver carp grown alone.

Yashouv (1969) reported the result of a study on the polyculture of carp, silver carp and tilapia. The ponds were regularly fertilized at 15 days intervals. After 189 days of stocking a net yield of 2350 kg/ha/yr. was obtained.

Yashouv and Halevy (1972) reported the result of a study on the polyculture of carp, silver carp and tilapia. The ponds were regularly fertilized at intervals of 15 days. After 189 days of stocking a net yield of 2350 kg/ha was achieved.

2.3 Economic Effect on Fish Production

Profitability of fish culture operation depends on many factors of which selection of species, stocking time, size of fingerlings, stocking densities and ratios and overall management practices are the guiding tools. Economy must dictate which methods or technologies a farmer should adopt to derive benefit from a particular production practice. Because economic analysis provides note only in the decision making of individual farmer but also in the information of aquatic policies. Only those literatures that are related to present studies are reviewed here.

Alam *et al.* (1995) evaluated the economics of different types of polyculture system involving exotic and native major carps. Fish yield of 1640-2995 kg/ha/7 months using the locally available inputs resulted in a net profit of Tk 52,055-87,641 /ha.

Awal *et al.* (1995) assessed the fish production and economic return of carp culture in six polyculture ponds. They recorded a net profit per hectare per 6 months for native, exotic and mixed polyculture system to be Tk. 30,825.00, Tk. 35,912.00 and Tk. 18,135.00, respectively through production of 1196, 1617 and 982 kg/ha/6 months, respectively.

Islam (1987 a, b) determined the effects of 7 inputs on pond fish production through the use of Cobb-Douglas production function model and all the surveyed inputs were found to have significant effects on pond output except the depth of pond water.

Islam and Dewan (1986) conducted a survey on the resource use and economic return of pond fish culture in four districts of Bangladesh and observed that pond fish production in the surveyed areas was based on stocking of fish seed, use of fertilizers and low quality rice bran as feed. The majority of the farmers in Gazipur, Mymensingh, Lakshmipur, Jessore district reared various species of native and exotic carps and produced 1,700 to 3,889 kg/ha/yr. in different locations. They further noted that higher yield was the factor for higher net return and price of the fish and economic use of both material inputs and labor influenced net return.

Khaleque *et al.* (1998) studied the economics of fish production under semi-intensive culture and management in Gazipur sadar, Kishoregonj and Gaffargaon Thana and showed that MAEP (Mymensingh Aquaculture Extension Project) fish farmers were producing fish at the rate of 324.5 MT/ha/yr. The production cost of fish ranged from Tk 80,712.00 to Tk 87,000.00/ha/yr. with an average BCR (Benifit Cost Ratio) value of 1.94. Fingerling cost was found to be the largest cost item followed by fish harvesting cost. They suggested that the fish farmers should form a fish-harvesting group on co-operative basis to minimize their production cost and to maximize net return from pond fish farming.

Rahman *et al.* (1998) reported the results of studies on fish culture in seasonal ponds with a brief account of cost and return analysis. They used three stocking models comprising of three fast growing exotic carps along with either of tilapia, sharputi or mola. They found satisfactory yield with four species combinations such as silver carp, grass carp, mirror carp, and sharputi. Fish production was comparatively low in one model where mola (*Amblypharyngodon mola*) was stocked.

Saha *et al.* (1997) analyzed the cost of fish production in Netrokona Sadar, Ghatail, Bhaluka and Pakundia Thana. Cost of production showed that the large farms and the lowest incurred the highest cost by the small farms. The average per hectare fish yield was estimated to be 2644 kg and it varied greatly with locations. Using a Cobb-Douglas production function model, it was found that organic matter, inorganic fertilizer and fish seed significantly influenced fish production in the pond. The highest net return was observed in Ghatail where the farmers' production cost was lesser but market price of the fish were relatively higher.

Shang and Costa-Pierce (1983) advocated the necessity of economic analysis of fish culture operation with a view to find out different alternatives for ensuring high level of net revenue earning. Economic analysis provides not only in the decision making of individual farmer but also in the formulation of aquaculture policies.

Chapter-Three

MATERIALS AND METHODS

3.0 MATERIALS AND METHODS

3.1 Study Area and Duration

The experiment was carried out at Kandua village, Madaripur Sadar in Madaripur District, Bangladesh during the period of 31st August 2000 to 15th March 2001. The pond owners were the enlisted farmers of Madaripur BRAC office. The farmers were given training before starting the polyculture.

3.2 Experimental Ponds

All the ponds were rectangular in shape and processed similar size, depth and basin conformation. The surface area of each pond was 80 sq. meter with the depth ranged from 0.75-1.0 meter with good dikes to avoid the flooding problem. Bottom topography of the pond was mostly planed and the embankments were covered with grasses and shrubs. A total of nine ponds were selected to accommodate three treatments.

3.3 Experimental Design

To study the growth rate, survival rate and production potential of exotic fishes with Indian major carp, three treatments were given in the present experiment, each with three replications. The ponds undertaken in this experiment posses almost physiochemical characteristics and have a certain natural yielding capacity. The species combinations given in different treatments were:

Treatment-T1: Five species polyculture model comprising of indigenous species rohu, catla, mrigal and exotic species silver carp and grass carp.

Treatment-T2: Five species polyculture model comprising of indigenous species rohu, catla, mrigal and exotic species silver carp and thai pangus.

Treatment-T3: Five species polyculture model comprising of indigenous species rohu, catla, mrigal and exotic species grass carp and thai pangus.

3.4 Pond Preparation

Before stocking the fish fingerlings, all the ponds were properly prepared for the experiment. All kinds of aquatic vegetation like floating, emergent, submerged and spreading were removed manually. Broken dikes and holes were repaired for protecting of flood. The predators and undesirable species were removed by frequent netting and cleaned by rotenon at a rate of 5 ppm. A bamboo-framed feeding device measuring 5-ft length × 5-ft width was installed in each pond to supply grasses or soft vegetation for grass carp. This frame prevents the pieces of grass and leaves from spreading out over the pond.

Liming was done to neutralize soil, killing pathogenic bacteria (parasite and microorganisms), promoting biological productivity etc. The requirement and dose of liming depends on soil condition. The applied rate of liming was 250 kg/ha, fertilized with urea and triple super phosphate and manured with decomposed cowdung (1200 kg/ha) before stocking with the preferred type of fish fingerlings.

3.5 Stocking Density

Good quality fish fingerlings were collected from local nursery and transported to the pond site. The fishes were stocked at the rate of 11250 fingerlings/ha in all the treatments. The fingerlings were acclimatized before being released into the experimental ponds. Weights of each species of fishes were recorded respectively during stocking. The stocking density and species ratios in the present study are shown in table-1.

Table-1: Stocking density and species combinations under different treatments.

Treatments	Local name	Scientific name	No. of fish/pond	No. of fish /ha
T1				
	Rohu	*Labeo rohita*	25	3125
	Catla	*Catla catla*	15	1875
	Mrigal	*Cirrhinus mrigala*	15	1875
	Silver carp	*Hypophthalmichthys molitrix*	20	2500
	Grass carp	*Ctenopharyngodon idella*	15	1875
T2				
	Rohu	*Labeo rohita*	25	3125
	Catla	*Catla catla*	15	1875
	Mrigal	*Cirrhinus mrigala*	15	1875
	Silver carp	*Hypophthalmichthys molitrix*	20	2500
	Thai pangus	*Pangasius sutchi*	15	1875
T3				
	Rohu	*Labeo rohita*	25	3125
	Catla	*Catla catla*	15	1875
	Mrigal	*Cirrhinus mrigala*	15	1875
	Grass carp	*Ctenopharyngodon idella*	20	2500
	Thai pangus	*Pangasius sutchi*	15	1875

3.6 Fertilization

The ponds were fertilized fortnightly with urea and TSP at the rate of 24.7 kg/ha and 18.5 kg/ha respectively. The TSP was soaked in water for overnight then mixed with urea in the following morning and solution was spread over the pond surface. Besides this, all the ponds were manuring daily with liquid cow-dung at the rate of 200 g/decimal except the cloudy or rainy day. The measured quality of fresh cow-dung was kept in the earthen container (Charri) for overnight before spraying on the pond water. The fertilizers were used to enhance the production of plankton that serves as natural feeds for fish.

3.7 Supplementary Feeding

The supplementary feeds were applied daily at morning for better growth. Locally available medium-grade rice bran (75%) and mustered oil cake (25%) were given to the fish at the rate of 4% of their body weight. The supplementary feed was given to the fish in the form of small balls. For this purpose mustered oil cake was soaked overnight and then mixed with rice bran thoroughly and small balls were made with mixed ingredients. The daily ration (feed) was adjusted based on the determination of fish biomass through monthly sampling. Special care was taken for grass carp as the grass carp feeds on higher aquatic plants. Duck weeds and or soft grasses were also supplied to the grass carp at 20% of their body weight.

3.8 Monitoring of Water Parameters

The important parameters of pond water such as temperature, dissolved oxygen and pH were inspected and monitored regularly. Water temperature was recorded with Centigrade Thermometer (YSI, model 58, USA). Dissolved oxygen was recorded by DO meter (YSI, model 58, USA) and pH was recorded by pH meter (Jenway, model 3020, UK). To maintain plankton production the water color was always observed and secchi disc reading was taken sporadically. Transparency reading was always maintained above 25 cm applying fertilizer. Water color of the experimental ponds was green and light green.

3.9 Growth Measurement

The growth of fishes was monitored fortnightly from each pond through random sampling method. At least 10 fishes of each species were sampled with the help of a cast net for the determination of their total body weight. The growth gained by the fish was calculated by subtracting the previous weight from the corresponding weight at each fortnight. The following parameters were used to evaluate the growth:

$$\text{Weight gained (g)} = \text{Mean final growth (g)} - \text{Mean initial weight (g)}$$

$$\text{Percentage of weight gained} = \frac{\text{Weight gained (g)}}{\text{Initial weight (g)}} \times 100$$

$$\text{Net increase} = \text{Final weight (g)} - \text{Initial weight (g)}$$

$$\text{Survival rate (\%)} = \frac{\text{No. of harvested fish}}{\text{Initial No. of fishes}} \times 100$$

3.10 Harvesting

At the end of experiment, all the fishes were harvested by netting repeatedly with a fine meshed seine net from each pond. The final growth gained was recorded by measuring weight (g) of individual fish. All the fishes were sold to the fish trader.

3.11 Production (kg/ha)

The gross and net production (kg/ha) of fishes was calculated by the following formula:

$$\text{Gross production (kg/ha)} = \frac{\text{Survival rate} \times \text{Stocking density} \times \text{Final weight (g)}}{100 \times 1000}$$

$$\text{Net production (kg/ha)} = \frac{\text{Survival rate} \times \text{Stocking density} \times \text{Net increase (g)}}{100 \times 1000}$$

3.12 Data Analysis

Statistical analysis for correlation of coefficient, standard deviation and graphical representation were conducted on PC using Microsoft Excel (Version 5) program.

3.13 Benefit Cost Analysis

Cost-benefit ratio was calculated by the following formula given by (Loudon and Loudon, 2000).

Total cost (Tk.) = Fertilizer+Lime (Tk.)+ Feed (Tk.)+ Fry (Tk.)+ Miscellaneous (Tk.)
Miscellaneous (Tk.) = Labor + Maintenance cost
Total yield (kg/ha) = Gross production
Total income (Tk.) = Commodity selling price per unit × Total yield
Total net income (Tk.) = Total income (Tk.) – Total cost (Tk.)
Rate of return % = (Total income/Total cost) × 100
Benefit Cost Ratio = Total income/Total cost.

Chapter-Four

RESULTS

4.0 RESULTS

4.1 Physico-chemical Parameters

4.1.1 Water Temperature (^{0}C)

The average water temperature was recorded as maximum 24.09±4.09 ^{0}C in treatment T1 and minimum 3.71± 3.77 ^{0}C in treatment T2 (Annex-Ia and Figure-2) during the study period. Fortnightly variations of average water temperature was recorded as maximum 29.40±0.70 ^{0}C in 31st August and minimum 18.00±0.64^{0}C in 1st February in treatment T1. In treatment T2 and T3, the maximum value was recorded 28.44±0.58 ^{0}C in 1st October and 29.30±0.70 ^{0}C in 31st August, and the lowest was 18.18±0.43 ^{0}C and 17.81±0.45 ^{0}C both in 1st February respectively (Annex-Ia and Figure-1).

4.1.2 Dissolved Oxygen (mg/L)

The average dissolved oxygen content was found to be highest 6.87 ±0.46 mg/L and the lowest 6.45± 0.71 mg/L in treatment T1 and T3 respectively (Annex-Ib and Figure-4). Fortnightly variations of dissolved oxygen content was recorded to be highest 7.69±0.14 mg/L in 15th December, 7.46±0.12 mg/L in 15th February and 7.55±0.08 mg/L in 15th February in treatment T1, T2 and T3 respectively. The lowest was recorded 6.34±0.12 mg/L in 1st December, 5.69±0.07 mg/L in 15th October and 5.40±0.26 mg/L in 31st August in treatment T1, T2 and T3 respectively (Annex-Ib and Figure-3).

4.1.3 pH

The average values of pH was found to be highest 6.81 ±0.46 and the lowest 6.59± 0.47 in treatment T2 and T3 respectively (Annex-Ic and Figure-6). The fortnightly variation of pH values were found to fluctuate between 6.15±0.05 (15th September) to 7.50±0.22 (31st August) in treatment T1, 6.15±0.12 (1st December) to 7.80±1.0 (31st August) in treatment T2 and 6.16±0.11 (1st January) to 7.00±0.13 (31st August) in treatment T3 that (Annex-Ic and Figure-5).

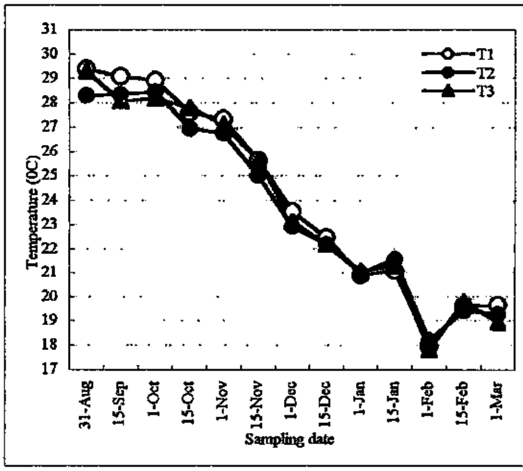

Figure-1: Fortnightly variation of water temperature (0C) in different treatments during the study period.

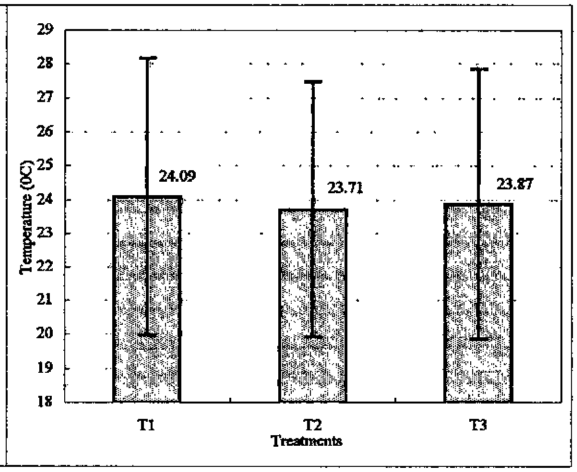

Figure-2: Variation of water temperature (oC) in different treatments during the study period.

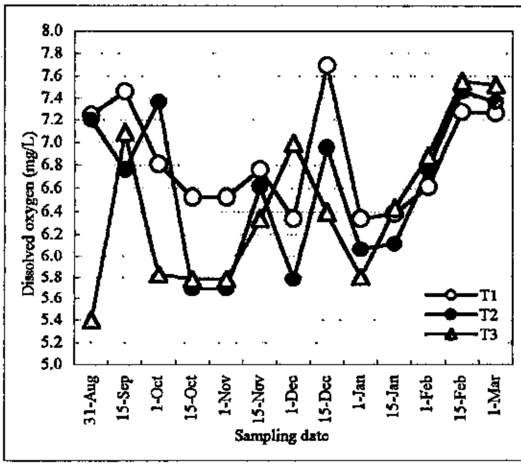

Figure-3: Fortnightly variation of dissolved oxygen (mg/L) in different treatments during the study period.

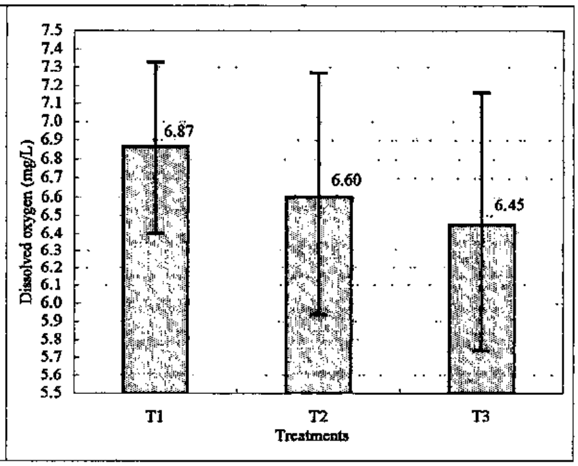

Figure-4: Variation of dissolved oxygen (mg/L) in different treatments during the study period.

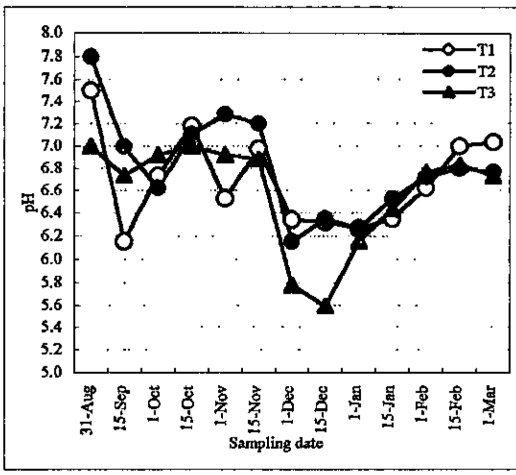

Figure-5: Fortnightly variation of pH in different treatments during the study period.

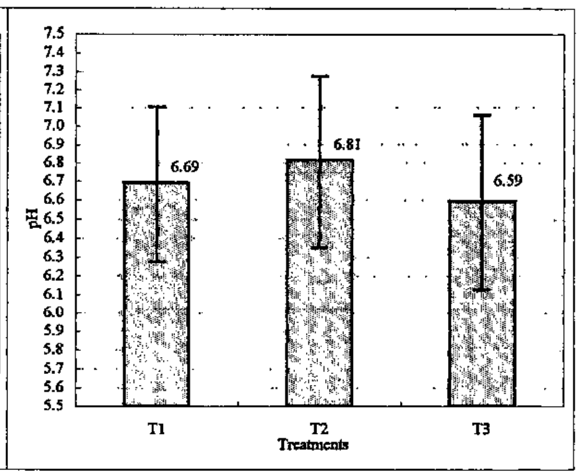

Figure-6: Variation of pH in different treatments during the study period.

4.2 Growth Performance of Fishes

Fortnightly variations of average weight (g) of fishes in different treatments are shown in Table-2 and Figure-7, 8 and 9. By percentage of increase the growth of all the species in all the treatments showed more or less gradual decrease from the beginning towards the end of the experiment. The lowest percentage increase in weight was recorded 4.53, 5.05, 7.43, 4.95 and 5.25 for rohu, catla, mrigal, silver carp and grass carp in treatment T1; 6.10, 4.45, 5.05, 5.1 and 4.8 for rohu, catla, mrigal, silver carp and thai pangus in treatment T2 and 7.20, 4.01, 4.11, 4.23 and 4.89 in treatment T3 respectively in 15th February. But slightly increase was showed 6.78, 6.96, 7.85, 5.56 and 7.25 for rohu, catla, mrigal, silver carp and grass carp in treatment T1; 8.66, 6.96, 7.34, 6.15 and 5.47 for rohu, catla, mrigal, silver carp and thai pangus in treatment T2 and 9.16, 6.23, 5.96, 5.68 and 6.24 in treatment T3 respectively in 1st March.

Table-2: Fortnightly weight increase in percentage in different treatments during the study period.

	Weight increase in percentage											
Species	15-Sep	1-Oct	15-Oct	1-Nov	15-Nov	1-Dec	15-Dec	1-Jan	15-Jan	1-Feb	15-Feb	1-Mar
T1												
Rohu	85.78	68	56.87	38.98	24.75	21.86	19.96	15.96	8.06	7.2	4.53	6.78
Catla	90.78	85.3	68.87	40.98	27.25	16.86	9.96	8.96	6.06	5.2	5.05	6.96
Mrigal	86.78	65.21	45.87	39.98	22.53	22.86	20.96	14.96	12.06	8.2	7.43	7.85
Silver carp	91.78	72.5	64.87	41.98	28.33	23.86	19.96	7.96	5.06	5.56	4.95	5.56
Grass carp	83.78	57.25	36.87	33.98	29.5	27.86	26.96	8.96	7.06	9.2	5.25	7.25
T2												
Rohu	87.78	76.3	54.87	35.98	27	17.75	15.23	8.46	7.06	6.2	6.1	8.66
Catla	90.78	77.3	72.87	41.98	26.4	13.86	9.33	7.58	5.21	4.52	4.45	6.96
Mrigal	87.78	83.45	43.87	33.98	19.25	15.25	14.35	7.85	6.36	5.78	5.05	7.34
Silver carp	91.78	51	74.87	57.98	31	16.65	12.56	6.99	6	5.46	5.1	6.15
Thai pangus	81.78	57	45.87	44.98	34	19.86	16.96	8.51	7.25	5.1	4.8	5.47
T3												
Rohu	82.78	64	51.87	44.58	19	22.7	14.75	13.96	9.14	8.2	7.2	9.16
Catla	94.65	85	63.87	39.21	22.65	17.36	12.85	11.23	6.06	4.28	4.01	6.23
Mrigal	85.78	55.23	50.35	32.34	27.56	14.56	11.11	10.4	5.45	4.52	4.11	5.96
Grass carp	82.78	63.2	32.15	35.64	24.15	15.3	11.89	10.1	5.19	4.92	4.23	5.68
Thai pangus	78.55	54.13	58.23	34.57	24.58	23.26	20.58	10.8	9.56	5.72	4.89	6.24

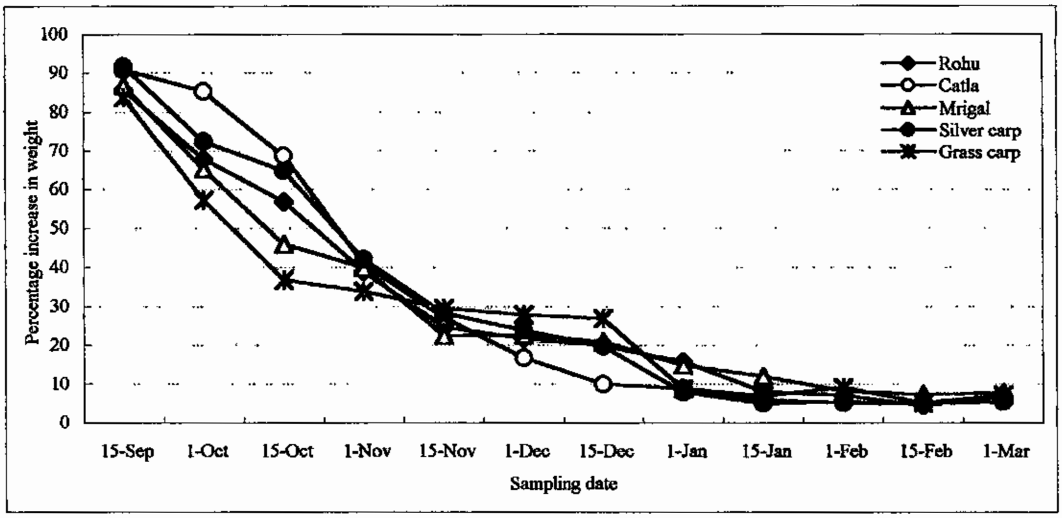

Figure-7: Fortnightly variation of percentage increase in weight during the study period in treatment T1.

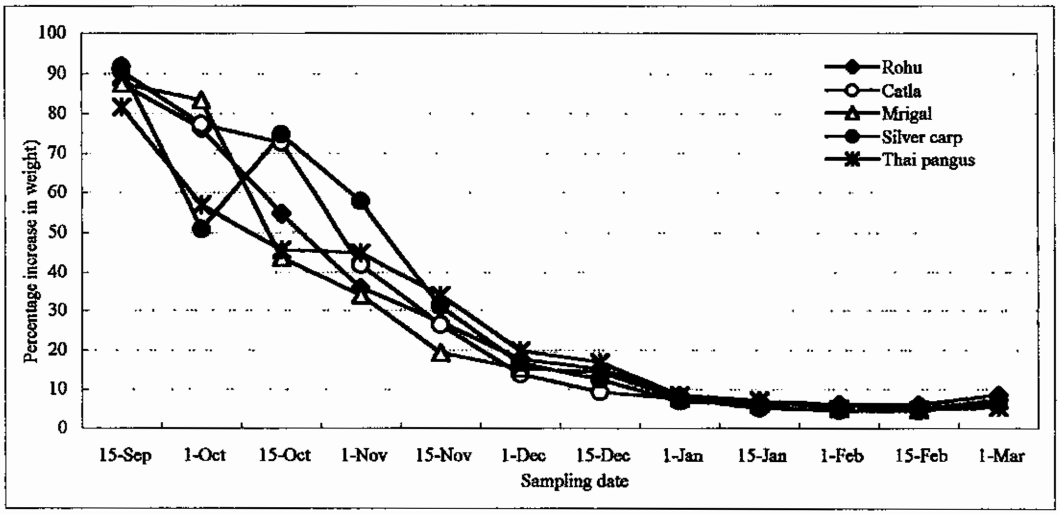

Figure-8: Fortnightly variation of percentage increase in weight during the study period in treatment T2

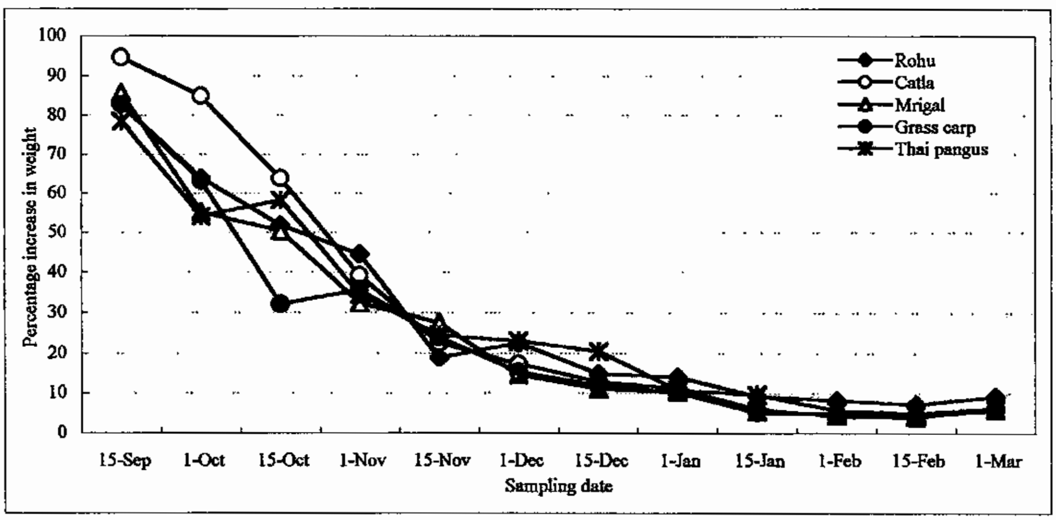

Figure-9: Fortnightly variation of percentage increase in weight during the study period in treatment T3.

4.3 Survival Rate

At the end of the experiment the survival rate of fishes of each species for each treatment was estimated separately and the values so far recorded have been showed in Annex-III and Figure-10, 11 and 12. The highest survivability was recorded as 80.68 % in treatment T1 followed by treatment T2 (76.69 %) and treatment T3 (72.99 %). Rohu showed the highest survival rate 85.35 % in treatment T1 and the lowest 78.55 % in treatment T3. Catla showed the highest survival rate of the same 81.29 % in treatment T1 and T2 and the lowest 75.43 % in treatment T3. Mrigal showed the highest survival rate 77.87 % in treatment T1 and the lowest 69.18 % in treatment T3. Silver carp showed the highest survival rate 84.88 % in treatment T2 and the lowest 77.25 % in treatment T1. Grass carp showed the highest survival rate 81.64 % in treatment T1 and the lowest 70.85 % in treatment T3. While thai pangus showed the same survival rate 67.24 % in treatment T2 and T3.

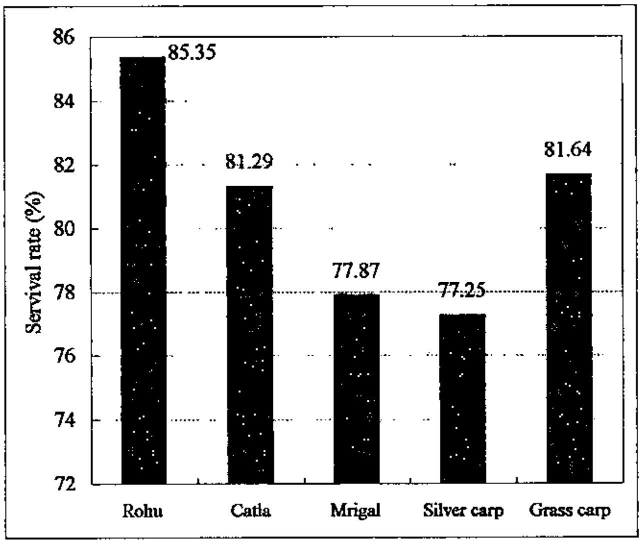

Figure-10: Average survival rate of different species in treatment T1.

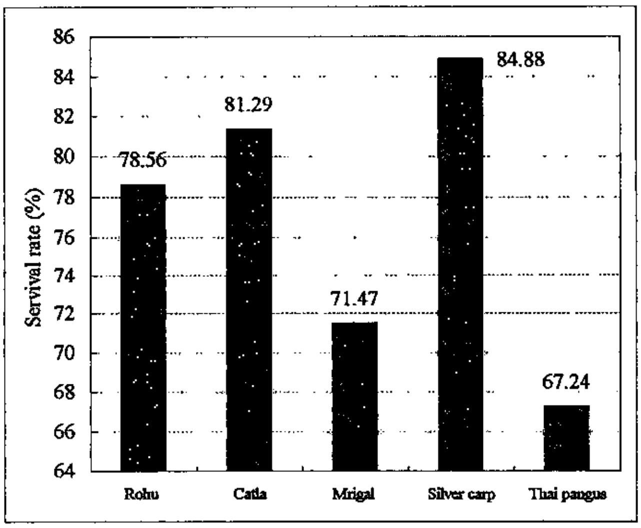

Figure-11: Average survival rate of different species in treatment T2.

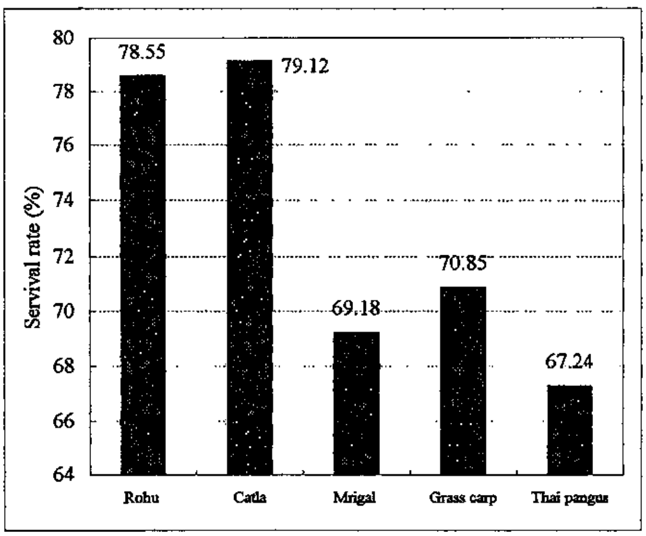

Figure-12: Average survival rate of different species in treatment T3.

4.4 Production (kg/ha)

The gross and net production of fish in different treatments in the experimental period is shown in Annex-III and Figure-13. Among the three treatments the highest production of fish both by gross and net was recorded as 1965.68 kg/ha and 1860.03 kg/ha in treatment T1 and the lowest was 1299.80 kg/ha and 1215.35 kg/ha in treatment T3 respectively. Also the gross and net production in treatment T2 was found 1639.76 kg/ha and 1543.49 kg/ha respectively.

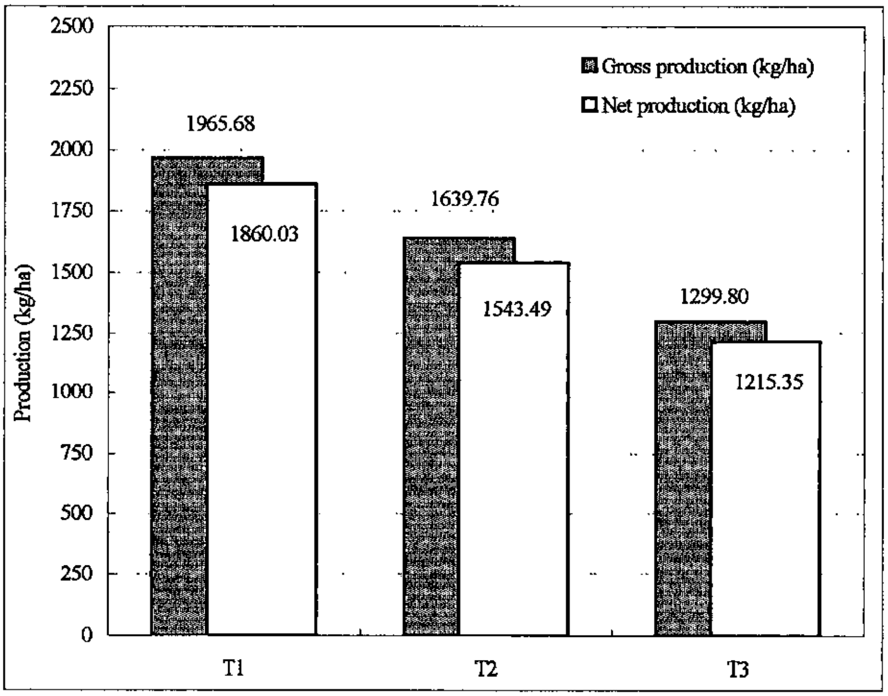

Figure-13: Gross and net production in different treatments in the study period.

4.5 Benefit Cost Analysis

The total costs were estimated as Tk 27546.00, Tk. 28389.75 and Tk. 28389.75 for treatment T1, T2 and T3 respectively (Annex-IVa and Figure-14). The gross income was estimated as Tk. 64190.25, Tk. 53888.36 and Tk. 46216.54 in treatment T1, T2 and T3 respectively (Annex-IVa). Therefore, the benefit cost ratio in the experimental ponds under the selected stocking models was found as 2.33, 1.90 and 1.63 in treatment T1, T2 and T3 that is shown in Annex-IVb and Figure-15. By analyzing marginal rate of return and the benefit cost ratio it could be concluded that treatment T1 is the most profitable than the other two treatments in giving lucrative economic return.

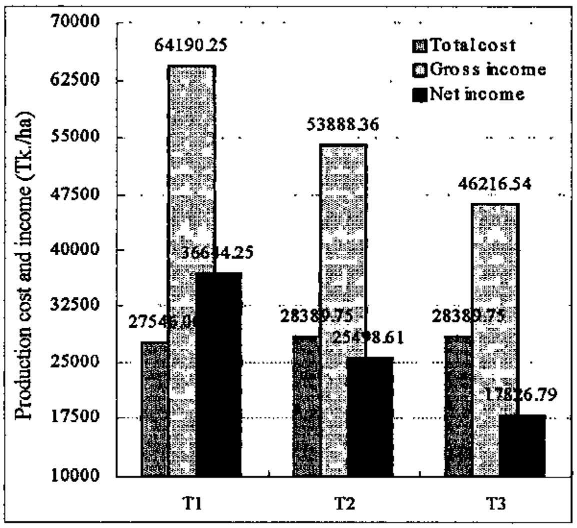

Figure-14: Total cost, gross and net income (Tk./ha) in different treatments.

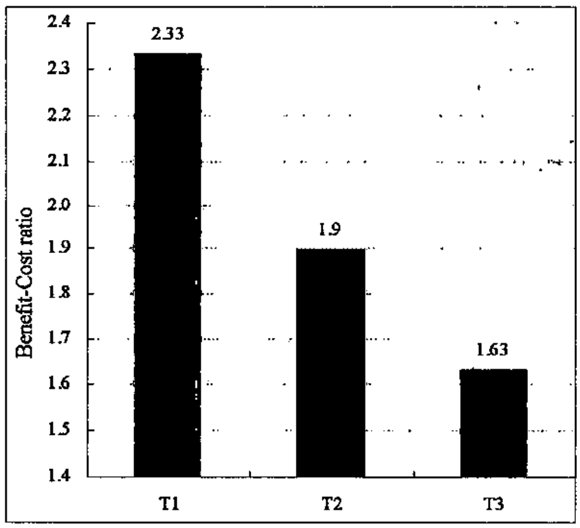

Figure-15: Benefit-Cost ratio in different treatments.

4.6 Interpretation of Results

4.6.1 Relation between Physico-chemical Parameters and Fish Production of Fishes in Different Treatments

The relation between physico-chemical parameters and production of fishes in different treatments are showed in Table-3 and Figure-16, 17 and 18. During the study period, production showed highly positive relation (r=0.984) with dissolved oxygen. Also production was found to be positively correlated with temperature (r=0.564) and pH (r=0.466) in all treatments.

Table-3: Relationship between Physico-chemical parameters and net production (kg/ha) of fishes.

Parameters	Regression equation (y on x)	Correlation coefficient "r"	Value of 't'	't' table value at 5% level	't' table value at 1% level
Temperature	y=-21119.4+948.4159x	0.564	8.19162*		
DO	y=-8297.19+1481.24x	0.984	8.28756*	4.302656	9.924988
pH	y=-7546.02+1356.535x	0.466	8.28316*		

*Insignificant at 1% level, but significant at 5% level.

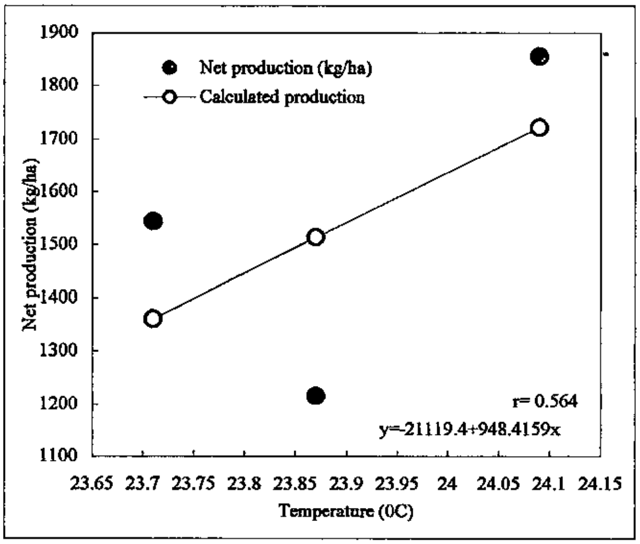

Figure-16: Regression of y between Temperature (0C) and production (kg/ha) in treatment T1.

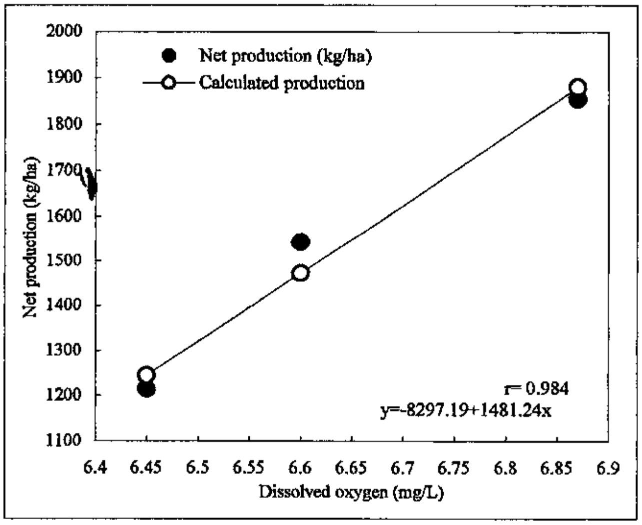

Figure-17: Regression of y between dissolved oxygen (mg/L) and production (kg/ha) in treatment T2.

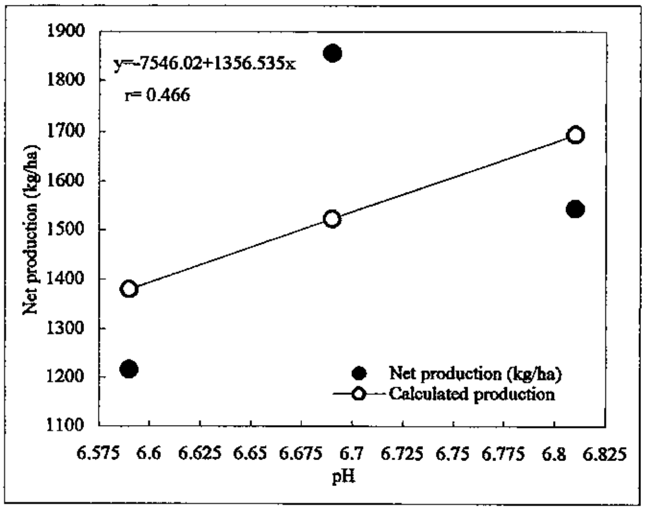

Figure-18: Regression of y between pH and production (kg/ha) in treatment T3.

4.6.2 Relation between Initial Weight (g) and Net Weight (g)

The relation between initial average weight and net average weight of fishes in different treatments is shown Table-4 and Figure-19, 20 and 21. Treatment T1 (r=0.930) and treatment T2 (r=0.989) showed highly positive relation but treatment T3 (r=0.887) showed moderate relation between initial and net weight.

Table-4: Relationship between Initial Weight (g) and Net weight (g).

Treatments	Regression equation (y on x)	Correlation coefficient "r"	Value of 't'	't' table value at 5% level	't' table value at 1% level
T1	y=-20.1524+19.15903x	0.930	8.343292*		
T2	y=44.4913+19.78228x	0.989	5.437063*	2.776451	4.6040805
T3	y=-51.3267+19.32365x	0.887	4.809367*		

*Significant at 1% level

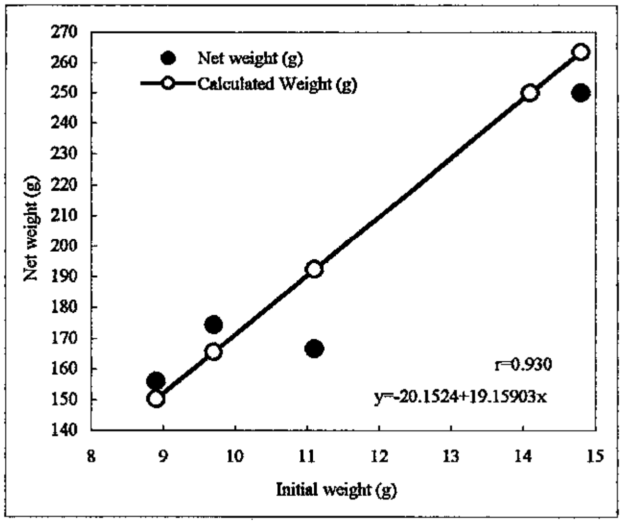

Figure-19: Regression of y between initial weight (g) and net weight (g) in treatment T1.

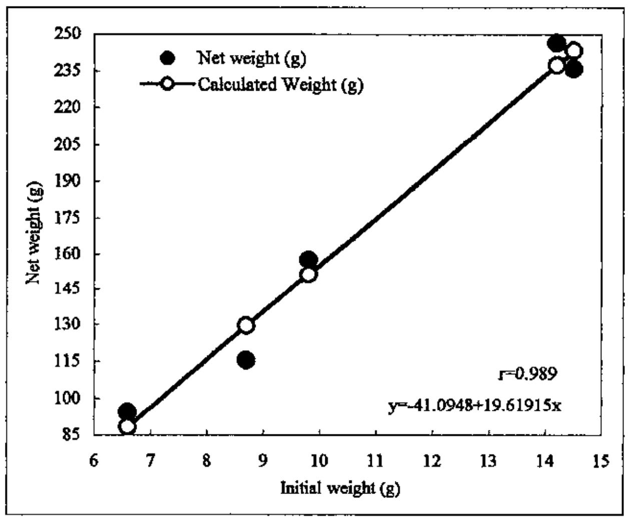

Figure-20: Regression of y between initial weight (g) and net weight (g) in treatment T2.

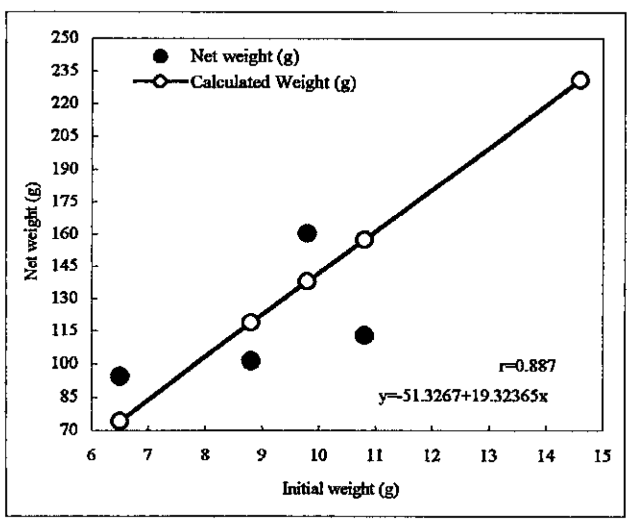

Figure-21: Regression of y between initial weight (g) and net weight (g) in treatment T3.

4.6.3 Relation between Survival Rate (%) and Net Production (kg/ha)

The relations between survival rate and net production of fishes in different treatments are showed in Table-5 and Figure-22, 23 and 24. Net production was found to positively correlated with survival rate in all treatments. The values of 'r' were estimated to be 0.110, 0.969 and 0.990 in treatment T1, T2 and T3 respectively. Treatments T3 showed better relation (r=0.990) between survival rate and net production.

Table-5: Relationship between survival rate (%) and net production (kg/ha)

Treatments	Regression equation (y on x)	Correlation coefficient "r"	Value of 't'	't' table value at 5% level	't' table value at 1% level
T1	y=14.513223+4.4310074x	0.110	4.99192*		
T2	y=-1432.74+22.70811x	0.969	3.20204**	2.776451	4.6040805
T3	y=-1483.58+23.65664x	0.990	3.02440**		

*Significant at 1% level ** Significant at 5% level

Chapter-Five

DISCUSSION

5.0 DISCUSSION

5.1 Physico-chemical Parameters

5.1.1 Water Temperature (^{0}C)

Temperature, one of the important physico-chemical parameter, which influences the physical, chemical and biological nature of water body. The water temperature found to fluctuate between 18 ^{0}C to 29 ^{0}C during the study period. Ali *et al.* (1982) stated that 20.5-36.5 ^{0}C is favorable for fish culture but Rahaman *et al.* (1982) stated the favorable temperature is 26.06-31.97 ^{0}C.

The temperature was maximum during 31 august and minimum during 1st February (Annex-Ia). Durve and Bal (1961) and Lakshmanan *et al.* (1967) also gave the same opinion.

The values of Water temperature were found to decrease gradually from October to till February. This trend might be due to cold weather.

5.1.2 Dissolved Oxygen (mg/L)

Dissolved oxygen was ranged from 5.40 to 7.55 mg\L (Annex-Ia). George (1981) stated, the productive range of dissolved oxygen is 4.5-9.9 mg\L. Ali *et al.* (1982) stated the favorable range is 7.2-10.5mg\L. Banerge (1967) reported 7.0 mg\L of dissolved oxygen of water body is good for productivity whereas the range from 3.0-5.0 mg\L is unproductive for fish culture. Mascid *et al.* (1998) stated, the significant variation of dissolved oxygen is 4.3-8.1 mg\L. Bhuyan (1970) reported dissolved oxygen content from 5.0-7.0 mg\L is required for high production.

During the study period, the overall dissolved oxygen content of pond water was found to maximum during winter and early spring (Annex-Ia). Dewan (1973) and Islam *et al.* (1978) reported the maximum values of dissolved oxygen in winter and minimum in summer. Pahwa and Mehrotra (1966) stated, the dissolved oxygen values are maximum during winter and minimum of the same during July and August.

The high concentration of dissolved oxygen content during winter was possibly due to low temperature, low rainfall and low pH. Due to the less temperature and low rainfall, the decomposition of organic matter was reduced with low production of carbon-de-oxide and less consumption of dissolved oxygen.

It is observed from the Figure-4 that treatment T1 was showed less fluctuatioh of dissolved oxygen than the other treatments. It may contribute the better growth performance of fishes in treatment T1.

5.1.3 pH

The pH values were almost neutral (5.60-7.80) during the study period which indicates good productivity of the pond water. Singh and Singh (1975) and Mascid *et al.* (1998) stated the results. Bhuyan (1970) and Martyshev (1983) stated the pH values are optimum values for Carps. Michael (1969) reported the pH ranging between 7.3 and 8.4 are the most suitable for fish culture.

The highest pH value was recorded in August and the lowest in December during the study period. Verma (1969) found the same result. He stated the highest values of pH during summer and the lowest of the same during winter.

The low pH values was recorded during winter possibly due to the low water temperature, less alkalinity, high dissolved oxygen and low rainfall. Verma (1969) stated heavy influx of water decrease the pH value.

5.2 Growth Performance of Fishes

The fortnightly average growth of fishes was recorded to increase more or less rapidly at the beginning of the experiment and decreasing gradually to till February. After that the growth of fishes was increased slightly during March in all treatments. The relatively slower growth of fishes was found at the end of experiment. Possibly, it occurred for the gradual decreasement of the water temperature i.e. the winter season. Sutlon (1974) found the same features. He reported that the growth rate of fishes depends on water temperature. During winter the growth rate of fishes are slower.

The better growth of fishes was found in treatment T2 (r=0.989) followed by treatment T1 (r=0.930) and treatment T3 (r=0.887). Among all species silver carp showed the highest growth both by net increase and percentage of increase in the study period. Ariza and Romero (1993) also recorded the highest growth of silver carp than the other species in polyculture system. Vesudevappa *et al.* (1989) stated that silver carp showed the best growth followed respectively catla, rohu and mrigal.

The growth of catla, rohu and mrigal occupied the successive position during the experimental period. Sukumaran *et al.* (1968) reported that the silver carp adversely affects the growth of catla.

Vesudevappa *et al.* (1989) recorded the highest growth rate of *H. molitrix* in polyculture, which was closely followed by catla, rohu and mrigal. However, among the three treatments catla showed the highest growth both by net increase and percentage of increase in treatment T3. This might be due to the absence of silver carp in this treatment as silver competes severely with catla. Dewan *et al.* (1991) recorded the greatest food overlap between catla and silver carp. Nandeesha and Rao (1989) reported silver carp as a voracious feeder of phytoplankton. Hepher *et al.* (1989) also reported that silver carp above a density of 1000/ha inhibit the growth of carps and tilapia.

Next to silver carp, rohu was found to contribute significantly to the total yield than the catla. This might be associated with less feed competition of rohu with silver carp. Less feed competition between silver carp and rohu was also reported by Dey *et al.* (1979) and they considered these two species was compatible species for polyculture.

However, among all the treatments relatively higher growth of fishes were recorded in treatment T2 except in few species than the other treatments.

5.3. Survival Rate

The highest survival rate 80.68 % was recorded in treatment T1 and the lowest 72.49 % in treatment T3 (Annex-III and Figure-10 and 12). Among all the species relatively higher survival rate was recorded in rohu in the present study that was closely followed by silver carp and catla. The lowest survival rate recorded in Pangus. Significant differences in survival rate were recorded among the different treatments. However, survival rates were better than the result of Saha *et al.* (1988).

5.4 Production of Fishes

The gross and the net production was recorded as highest subsequently followed by 1965.68 kg/ha and 1860.03 kg/ha, 1639.76 kg/ha and 1543.49 kg/ha and, 1281.48 kg/ha and 1198.04 kg/ha in treatment T1, T2 and T3 respectively. Treatment T1 showed the better production than the other two. This might be attributed to better combination of both exotic and indigenous species than the rest of treatments. Lakshmanan *et al.* (1971) obtained good result in polyculture with Chinese and Indian major carps by stocking in varying proportions in different densities. The fish production recorded by them varied from 2230-4209 kg/ha/yr.

Jhingran (1976), Chaudhuri (1978), Mathew *et al.* (1988) and Gupta *et al.* (1990) also reported good results from the polyculture of Indian major carps with exotic species and the yield recorded by them were 7000-9000 kg\ha\yr, 7444.8 kg\ha\ya, 10183 kg\ha\yr and 4917 kg/ha/yr. respectively. Whereas, Dunseth and Smitherman (1977) find out the effectiveness of polyculture using silver carp and bighead carp in catfish growout ponds. They noted the yield of catfishes reduce with the combination of carp.

The relatively low yield recorded in the present study might be attributed to shorter (6 months) stocking period and the colder rearing season.

5.5 Economic Return on Fish Production

The net profit was recorded 36644.25 Tk./ha, 25498.61 Tk./ha and 17826.79 Tk./ha in T1, T2 and T3 respectively. The rate of return was highest in T1 (232.59%) followed by treatment T1 and T2. T1 also showed the better benefit cost ratio (2.33) than the rest of treatments.

Alam *et al.* (1995) reported that the economics of different types of polyculture system involving exotic and native major carps. Fish yield of 1640-2995 kg/ha/7 months using the locally available inputs resulted in a net profit of Tk 52,055-87,641 /ha. Awal *et al.* (1995) stated that a net profit per hectare per 6 months for native, exotic and mixed polyculture system to be Tk. 30,825.00, Tk. 35,912.00 and Tk. 18,135.00, respectively through production of 1196, 1617 and 982 kg/ha/6 months, respectively.

It could be conclude that treatment T1 was more feasible than that of treatment T2 and T3 in terms of net and gross profit (Tk./ha), return of investment, benefit cost ratio and production rate.

Islam and Dewan (1986) noted that higher yield was the factor for higher net return and price of the fish and economic use of both material inputs and labor influenced net return. Khaleque *et al.* (1998) suggested that the fish farmers should form a fish-harvesting group on co-operative basis to minimize their production cost and to maximize net return from pond fish farming.

5.6 Overall Performance of the Study

Table-6: Comparative performance of different treatments during the study period

Treatments	Indication criteria	Remarks
T1		
	Better in terms of both gross (1965.68 kg/ha) and net (1860.03 kg/ha) production of fishes (Figure-13).	We know, thai pangus is a carnivore species. In Treatment T1 thai pangus were not stocked. Probably Treatment T1 showed the better production for that reason.
	Better in term of survival rate (80.68 %).	Probably, it caused due to the absence of carnivore species (thai pangus).
	Better in terms of benefit cost ratio (2.33) and return of investment (232.59).	The production rate in treatment T1 was higher so it showed the better performance.
T2		
	Better in terms of growth performance (r=0.989) (Figure-20).	The carnivore species, thai pangus consumed other species and decreased stocking density. As a result, rest of fishes got opportunity to take more food than the other treatments. For that treatment T2 showed the better growth performance during the study period.
T3		
	Better in terms of the relation between survival rate and net production (r=0.990) (Figure-24).	The survivability was lowest in treatment T3. Fishes got opportunity to take more food. As a result treatment T3 showed better production to compare with survival rate.

Chapter-Six

CONCLUSION

6.0 CONCLUSION

Bangladesh is trying hard to increase the annual fish production to fight the serious protein deficiency of her people. But the production of fish per unit area is still very low in comparison to other countries, mainly due to the lack of appropriate technical knowledge on fish culture. Moreover, they don't have enough capital to invest in this sector. In this situation, we have needed to recommend the applicable, economically effective technology to the fish farmer by which they are encouraged on pond fish culture. Therefore, an experiment was conducted to explore the fish production potential in ployculture system of both the indigenous and the exotic fish species in pond.

Three stocking models were designed as treatment T1, T2 and T3 with the stocking density of each at 11250 individual/ha. The species combination was rohu, catla, mrigal, silver carp and grass carp in Treatment T1; rohu, catla, mrigal, silver carp and thai pangus in Treatment T2 and rohu, catla, mrigal, grass carp and thai pangus in Treatment T3.

Comparatively, treatment T1 showed the significant result in respect to the survival rate (80.68 %) and the production (gross production 1965.54 kg/ha and net production 1855.90 kg/ha). Treatment T1 also showed better result on economic analysis including benefit cost ratio (2.33) and return of investment (232.39 %). Otherwise, growth performance (r=0.989) was found to better in Treatment T2 and treatment T3 showed the better result in respect to the relation between survivability and net production.

Considering the higher yield of fishes, benefit cost ratio and return of investment; the species combination is given in treatment T1 may be recommended for polyculture in pond for optimizing the yield of pond fish culture.

Chapter-Seven

REFERENCES

7.0 REFERENCES

Alam, A.K.M.N., Islam, M.A., Mollah, M.E.A., Haq, M.S. and Rahman. M.S., 1985. Growth of silver carp, *Hypophthalmichthys molitrix* (Val.) with references to some limnological parameters of rearing ponds. *Bangladesh J. Fish,* 8 (1-2): 9-15.

Alam, M.S., Miah, M.S., Neazuddin, M., Gupta, M.V. and Shah, M.S., 1995. Studies on fish production in farmers' ponds in carp polyculture system. *Bangladesh J. Fish,* 15-18 (1-2): 59-64

Ali, S., Rahman, A.K.A., Patwary A.R. and Islam, K.H.R., 1982. Studies on the diurnal variations in physico-chemical factors and zooplankton in a freshwater pond. *Bangladesh J. Fish,* 2-5 (1-2): 15-23.

Ariza, G.S. and Romero, G.P., 1993. Assessment of a white cachama (*Piaractus brachypomus),* red tilapia *sp. (Oreochromis sp.)* and silver carp *(Hypophthalmichthys molitrix)* polyculture. *Bol. cient. INPA no.* L, pp. *4-15.*

Awal, S., Wahab, M.A., Ahmed, G.U., Rahman, M.M. and Ahmed, F., 1995. Economics of different polyculture system involving native and exotic carp. *Bangladesh J. Fish.,* 15-18(1-2): 37-43.

Banerjea, S.M., 1967. Water quality and soil condition of fish ponds in some states of India in relation to 1-fish production. *Indian J. Fish,* 14:115-144s

Bhuyan, B.R., 1970. Physico-chemical qualities of some ancient tanks of Sibsagar, Assam. *Environ. Health,* 12: 12-134.

Blackburn, R.D. and Sutton, D.L., 1971. Growth of white amur *(Ctenopharyngodon idella* val.) *on* selected species of aquatic plans. *Proc. Eur. Weeds Res. Conc. Int, Symp. Aquat. Weeds,* 3: 87-93.

Buck, H., Baur, R.J. and Rose, C.R., 1978. Polyculture of Chinese carps in ponds with swine waste. In R.O. Smitherman, W.L. Shelton and J.H. Grover (Eds). Symposium on culture of exotic fishes. *Fish Culture Section, American Fisheries Society. pp.* 144-155.

Burke, J.S. Bayne, D.R. and Rea, H., 1986. Impact of silver and bighead carp on plankton community of channel catfish pond. Aquaculture. 55: 59-68.

Chaudhuri, H., Rao, N.G.S., Saha, G.N., Rout, M. and Ranaujia, D.R., 1978. Record fish production through Intensive fish Culture in a fanner's ponds *J. Inland Fish. Soc., India,* 10: 19-27.

Chowdhuri, H., Chakrabarty, R.D., Sen, P.R., Rao, N.G.S. and Jena, S., 1975. A new high in fish production in India with record yields by composite fish culture in freshwater ponds. Aquaculture. 6: 343-355.Control. *Vicksburg, Missouri, U.S. Army Engineer water ways Experiment station,* 44p p.

Davis, G.H., Bhuiyan, A.R. and Ammen, M., 1984. Fish Production in managed farmer's ponds with different feeding and stocking regimes. In Proc. 4th Seminar Max. Livestock Production from minimum land. Department of Animal Science, Bangladesh Agricultural University, Mymensingh.

Dewan, S., 1973. Investigation into the ecology of fishes of Mymensingh lake. Ph.D.Thesis submitted to the Department of Aquiculture and Management. Faculty of Fisheries, B.A.U., Mymensingh, 335p.

Dewan, S., Wahab, M.A., Beveridge, M.C.M., Rahman, M.H. and Sarker, B.K., 1991. Food selection, electivity and dietary overlap among plaktivorous Chinese and Indian major carp fry and fingerlings grown in extensively managed, rain-fed ponds in Bangladesh, *Aquaculture and Fish. Mariag.* 22: 277-294.

Dey, R.K., Reddy, P.V. Singh, B. and Murty, D.S., 1979. Notes on compatibility and competition between silver carp and rohu. *J. Inland Soc., India,* 11 (1): 125 - 135.

Dunseth, D.R. and Smitherman, R.O., 1977. Polyculture of catfish, tilapia, and silver carp. *Proc. Annu. Commercial Fisheries Workshop.* 6: 25 -26

Durve, V.S. and Bal, D.V., 1961. Hydrobiology of the Kelwaback water and adjoining sea. *J. Univ., Bombay,* 29: 39-48.

DOF (Directorate of Fisheries), 2001. Matshya Shapta Sharanika, pp 51-57, 65-66.

FAO/UNDP, 1985. Twenty Year Fishery Development Plan for Bangladesh. *J.C. Marr. Associates, USA. 321 pp.*

George, M.G., 1961. Diurnal variations in two shallow ponds in Delhi, India. *Hydroblol,* 18:265-273.

Gupta, V.K., Sharma, J.P. and Srivastava, J.B., 1990. Polyculture of Indian and exotic carps using cattle manurer with and without supplementary feed. *Recent- Trends-In Limnol. pp* 439-446.

Goolish, E.M. and Adelman, L.R., 1984. Effects of ration size and temperature on the growth of juvenile common carp (*Cyprinus carpio*) Aquaculture, 36: 27-35.

Gosh, A., Banarica, M.K. and Rao, L.H., 1973. Some observations on the cultural prospects of silver carp, *Hypophthalmichthys molitrix (Val.)* in sewage fed ponds. *J. Inland. Fish. Soc., India*, 5: 131-13

Gupta, V. K., Sharma, J. P. and Srivastava, J.B., 1990. Polyculture of Indian and exotic carps using cattle manurer with and without supplementary feed. *Recent-Trends-In Limnol.,* pp 439-446.

Halver, J.E. 1984. Special methods in pen fish husbandry. *Akademiai Nyomda, Budapest. pp* 146.

Hepher, B. and Milstein, M., 1989. Principles of Fish Nutrition, In: Fish culture in Warm Water System: *Problems and Trends. pp.* CRC Press, New York. USA.

Hossain, M.A., Toyub, M.A., Islam, M.N. and Hassan, M.R., 1994. Effect of species combination on the growth of Major and Chinese carp in demonstration ponds under Feni district. *Bangladesh J. Agril. Sci.* 21(2): 257-266.

Islam, M.A., Chowdliury, M.Y. and Karim, R., 1978. A comparative study of some physico-chemical factors and the growth of major carps on ponds. *Bangladesh J. Aquaculture.*, 1: 61-73

Islam, M.S. 1987a. Factors affecting pond fish production in North-West Bangladesh. *Bangladesh J. Agric. Econ.*, 10(l) . -87-93.

Islam, M.S. 1987b. Input-output relationship of pond fish culture in four selected districts of Bangladesh. *Bangladesh J. Ext. Edu.*, 2(2):39-45

Islam, M.S.and Dewan, S., 1986. Resource use and economic return in pond fish culture, a paper presented at the seminar on "Socio-economic Aspect of Developing Fisheries Resources in Bangladesh", B.A.U., Mymensingh, 25-26 June, 1986, 1 1 pp.

Janecek, V., Kepr, T. and Priluyl, L., 1984. Experimental rearing of stock carp (C2) in polyculture with silver carp and grass carp. *Bul. Vyzk. Ustav-ryb. Hydrobiol.* 20 (4): 3-11.

Jauncey, K., Matty, A.J., 1979. Mirror carp–fast grower with room temperature for expantion. *Fish farmer.* 2 (5): 29.

Jhingran, V.G., 1975. Aquaplosion Lecture, Summer Int. Intensive Freshwater Fish Culture, Cuttack, organised by centre Inland Fish. Res. Inst. Barrackpore (ICAR), pp.12.

Jhingran, V.G., 1976. System of polyculture in inland waters in *India. J. Fish. Res. Board, Can.*, 33: 905-910.

Jhingran, V.G., 1991. Fish and Fisheries of India. Hindustan Publishing Corporation, *India. Third edition, pp.* 42 1-433.

Kader, M., Mirza, J.A., Zaman, N. and Dewan, S., 1989. Observations of growth performances of exotic silver carp under polyculture system with Indian major carps. *Bangladesh J. Fish.* 12(2): 25-34.

Khaleque, M.A., Sultan, A.K.M. and Mirza, J.A., 1998. Economics of pond is farming under semi-intensive culture and management. *Bangladesh J. Train. Devt.*, 11(2).

Khan, H.A. and Jhingran, V.G., 1975. Synopsis of biological data on rohu, *Labeo rohita* (Hamilton, 1822). *FAO Fish, Synop.* (111): 100 pp.

Kohinoor, A.H.M., Akhteruzzaman, M. and Shah, M.S., 1993. Production of *Pungasius gonionotus* (Bleeker) in ponds, *Bangladesh J. Zool.,* 21(2): 77-83.

Lakshmanan, M.A.V., Sukumaran, K.K., Murty, D.S., Chakrabory, D.P. and Philipose, M.T., 1971. Preliminary observations on intensive fish farming in fresh water ponds by the composite culture of Indian and exotic species. *J. Inland Fish. Soc, India,* 3: 1-21.

Lakshmanan, M.A.V., Bhuiyan, B.R., Radhakrishna, S. and Babu, M., 1967. Survival and Growth of Cultivable Fishes in Assam Ponds. Ind. J. Fish., 14: 1-23.

Lakshmanan, M.A.V., Sen, P.R., Murty, D.S. and Chakraborty, D.P., 1969. Preliminary study on the rearing of carp fingerlings. *Indian J. Fish.* 15: 40-52.

Lakshminarayann, J.S.S., 1965. Studies on the phytoplankton of the river Ganges. Varanasia, India, Part 11. The physico-chemical characteristics of river Ganges. *Hydroblol.* 25 : 119-139.

Ling, S.W., 1977. Aquaculture in South East Asia, University of Washington Press, Seattle. 108 pp.

Loudon, K.C. and Loudon, J.P., 2000. Management Information Systems. 4th Edition.

Macan, T.T. and Maudsley, R., 1966. The temperature at moorland fish pond. *Hydrobiol.* 27: 1-22.

Malecha, S.R., Buck, D.H., Baur, R.J. and Onizuka, D.R., 1981. Polyculture of the freshwater prawn, *Macrobrachium rosenbergii,* Chinese and common carps in ponds enriched with swine manure. *Initial trials. Aquaculture,* 25: 101-116.

Martyshev, F.G., 1983. Pond Fisheries. *Amerind Publishing Co. Pvt. Ltd., New Delhi. India,* 29 p.

Mascid *et al.*, 1998. The Water Quality and Plankton Production in Derelict, Traditional and Semi-Intensive Fishes Ponds. *Bangladesh J. Train. Dev.*, pp. 57-61.

Mathew, P. M., Singh, B.K., Chakraborty, D.P., 1988. A case study - stocking of fry in six species composite Fish culture. *J. Maharashtra Agric. Univ.*, 13 (1): 79-82.

Michael, R.G., 1969. Seasonal trends in physico-chemical factors and plankton of freshwater fish ponds and their role in fish culture. *Hydrobiol.*, 33 (1): 144 – 160.

Michewicz, J.E., Sutton, D.L. and Blackburn, R.D., 1972. Water quality of small enclosures stocked with white amur, *Hyacinth control. J.* 10: 22-5.

Milstein, A., 1990. Fish species interactions. EIFA and FAO symposium on production enhancement in still water pond culture, 15-18 May 1990.

Mirza, J.A., Islam, R., Haque, A.K.M.A. and Chowdhury, M.Y., 1978. Studies on the physico-chemical characteristics of the river Old Brahmaputra at Mymensingh. *Bangladesh J, Aquaculture.* 1 (1) : 33-4 1.

Moav, R., Wohlfarth, G.W., Schroeder, G.L., Hulata, G.L. and Barash, H., 1977. Intensive polyculture of fish in fresh water ponds. *Aquaculture,* 10: 25-43.

Murty, D.S., Saha, G.N., Selvaraj, C., Reddy, P.V.G.K. and Dey, R.K., 1978. Studies on increased fish production in composite fish culture through nitrogenous fertilization with and without supplementary feeding. *J. Inland Fish. Soc., India.* 1039745.

Nandeesha, M.C. and Rao, K.G., 1989. Recent developments in carp culture technology in India with special reference to the state of Andhra Pradesh.

Newton, S.H., Dean, J.C. and Nandcoelk, A.J., 1978. Low intensit y polyculture with Chinese carps. In: R. 0. Smitherman, J.H. Grover and W. L. Shalton (eds.). Culture of exotic fishes, pp. 137-143.

Oppenheimer, J.H., Alimed, M.G., Huq, A., Haque, K.H., Alam, A.K.M.A., Aziz, K.M. S., Ali, S. and Haque, A.S.M.M., 1978. Limnological studies of three ponds in Dhaka. *Bangladesh. J. Fish,* 1 (l): 1-28.

Opuszynski, P., 1986. Polyculture in carp ponds in R. Billard and J. Marcel. Aquaculture of Cyprinids. INRA, Paris, France, pp. 269 -281.

Pahwa, D.V. and Mehrotra, S.N., 1966. Observations of fluctuations in the abundance of plankton in relation to certain hydrobiological condition of river the Ganga. Proc. Nat. Acad. Sci., India, Soc., B, 36: 157-189.

Rahman, H.S., Chowdhury, M.Y., Haque, A.K.M.A. and Haq, M.S., 1982. Limnological studies of four ponds. *Bangladesh J. Fish.,* 2-5(1-2): 25-35.

Rahman, M., 1996. Effect of stocking size on the growth, survival and production of carps under polyculture system. M.Sc. Thesis, Department of Aquaculture and Management, B.A.U., Mymensingh, 51 pp.

Rahman, M.S. and Rahman, M.A., 1998. Effects of stocking density and species combination on fish production in ponds. *Bangladesh J. Train. Dev.*, 11(1-2): 191-197.

Saha, N.C., Islam, M.S. and Saha, J.K., 1997. Economics of pond fish production in some selected areas of Bangladesh. *Bangladesh J. Aquaculture,* 10 (1-2) in press.

Saha, S.B., Gupta, M.Y. and Sahabuddin, M., 1989. Studies on the comparative efficiency of different fertilizers on the production of silver carp *(Hypophthalmichthys molitrix)* fry in nursery ponds. *Bangladesh J. Fish.* 12(1): 11-20.

Saha, S.B., Gupta, M.V., Hossain, M.G. and Shah, M.S., 1988. Growth and survival of rohu (*Labeo rohita*) fry in rearing ponds at different stocking densities. *Bangladesh J. Fish.* 16(2): 119-126.

Schroeder G., 1974. Use of fluid cowshed manure in fish ponds. Bamidgeh. 26: 84-96.

Schroeder, G.L. and Hepher, B., 1979. Use of Agricultural and Urban wastes in fish culture. In: T.V.R. Pillay, and W.A. Dill (Eds.) Advances in Aquaculture. pp. 487-489. Fishing News Books Ltd., Farnham, England.

Schroeder, G., 1975. Some effects of stocking fish in waste treatment ponds. Water Res. 9: 591-593.

Shahabuddin, M., Malek, A., Deppert, D., Perschbaer, P. and Shah, M.S., 1987a. Effect of inorganic fertilizers. 1. On the growth of carp fingerling in composite culture. *Bangladesh Fish.* 10 (2): 57-61.

Shahabuddin, M., Malek, A., Deppert, D., Perschbacher, R. and Shah, M.S., 1987b. Effect of inorganic fertilizers, II. On the growth of rohu fingerlings in monoculture at high density. *Bangladesh Fish.* 10(2): 63-66.

Shang, Y.C. and Costa-Pierce, B.A., 1983. Integrated agriculture-aquaculture-farming system- some economic aspects. *J. World Maricult. Soc.,* 14: 523-530.

Shepherd, J. and Bromage, N., 1992. Intensive fish farming. *Blackwell Scientific Publications.* Oxford, Great Britain; UK., pp. 306-307.

Singh, C.S. and Singh, K.P., 1975. Feeding experiments on Indian major carps in Terai ponds. *J. Inland Fish Soc. India,* 7-. 212-215.

Singh, S.B., Sukumaran, K.K., Chakraborti, P.C. and Bagchi, M.M., 1972. Observatiori on composite culture of Indian major carps and exotic carps. *J. Inland Fish. Soc. India,* 4: 38-50.

Sinha, V.R.P. and Gupta, M.V., 1974. Composite cuture of Indian and exotic fisheries at Kalyani. Indian Fmg., 24 (4): 29-3 1.

Spataru, P., 1977. Gut contents of silver carp (Val.) and some tropic relations to offer fish species polyculture system.

Spataru, P., Hepher, B. and Halevy, A., 1980. The effect of method of supplementary feed application on the feeding habits of common carp (*Cyprinus carpio*) with regard natural food in ponds. *Hydrobiologia.* 72 (1- 2): 171 –178.

Stanty, J.G., 1975. Production of monosex white amur for aquatic plant control. Final report to the U.S.A army crops of Engineers, Aquatic plant.

Sukumaran, K.K., Singh, S.B., Murty, D.S. and Chakraborty, P.C., 1969. Studies on compatibility and competition between silver carp, and catla. *Proc. Indo. Pacific Fish. Coun.*, 13 (2): 185-194.

Sukumaran, K.K., Singh, S.B., Murty, D.S. and Chakraborti, P.C., 1968. Studies on compatibitity and competition between silver carp, Hypopthalmichthys molitrix (Val.) and catla, Catla catla (Ham) Proc. *Indo-Pacific Fish. Coun.* 13(2): 185-194.

Sutton, D.L., 1974. Utilization of hydrilla by white amur Hyacinth control J., 12: 66 –70.

Tal, S. and Ziv, I., 1978a. Culture of exotic fishes in Israel in Symposium on culture of exotic fishes presented at Aquaculture/ Atlanta/78, Atlanta, Georgia, and January 4, 1978. Edited by R.D. Smitherman, W.L. Shelton and J.H. Grover. pp. 1-9.

Tal, S. and Ziv, I., 1978b. Culture of exotic species in Israel. *Bamidgeh.* 30 (l): 3-11.

Tang, Y.A., 1970. Evaluation of balance between fishes and available fish foods in multi species fish Culture ponds ill Taiwan. *Trans. Arn. Fish, Soc.*, 99: 708-718.

Uddin, M.S., Shadullah, M., Ali, M.S., Shah, M.S. and Alam, M.J., 1987. Effect of stocking ratios on the growth of fishes under carp polyculture system. *Bangladesh J. Fish. (Accepted).*

Verma, M.N., 1969. Hydroblological study of a tropical impoundment Tekanpur Reservoir Gwalior, India, with special reference to breeding of Indian carps, *Hydrobiol.*, 32 (3-4) :358-368.

Vesudevappa, C., Ramesh, K.S. and Reddy, P.N., 1989. Silver carp-a boon to maximize fish yield in pond culture. Workshop on exotic aquatic species in India. *Bangalore (India). Joseph, M. M. ed.* 1989, 1: 109-112.

Wahab, M.A., Islam, M.T., Ahmed, Z.F., Haq, M.S., Haque, M.A. and Biswas, B.K., 1994. Effect of frequency of fertilization on the pond ecology and growth of fishes, BAU Res. Prog., 9: (in press).

Wahab, M.A., Ahmed, Z.F., Islam, A. and Rahmatifflah, S.M., 1995. Effect of introduction of con-irrion carp, Clyprim.tv eai-pio (L.) on the pond ecology

Wohlfarth, G.W. and Hulata, G., 1987. Use of manure in aquaculture. In: D.J. W. Moriaty and R.S.V. Pulling (Eds.) Detritus and microbial ecology in aquaculture. Pp. 335-367. ICLARM Conference Proceedings 14. Manila, Philippines.

Yashouv, A., 1969. The fish pond as an experimental model for study of interactions within and among fish populations. *Verh. Internat. Verein. Limnol,* 17-582-593.

Yashouv, A., 1971. Interaction between the common carp and silver in fish ponds Bamidgeh. 23(3): 85-100.

Yashouv, A. and Halevy, A., 1972. Experimental studies of polyculture in 1971. Bamidgeh, 24(2): 31-39

Zafar, A. R., 1964. On the ecology of algae in certain fish ponds of Hyderabad. India. 1. Physico-chemical complexes. *Hydrobiol.,* 23 : 179-195.

Chapter-Eight

APPENDICES

Annex-Ia: Fortnightly variation of average temperature in different treatments during the study period.

Treatments	31-Aug	15-Sep	1-Oct	15-Oct	1-Nov	15-Nov	1-Dec	15-Dec	1-Jan	15-Jan	1-Feb	15-Feb	1-Mar	Average	SD
T1	29.40	29.09	28.91	27.60	27.32	25.64	23.54	22.47	20.89	21.07	18.00	19.58	19.63	24.09	4.09
T2	28.30	28.35	28.44	26.95	26.76	24.99	22.94	22.19	20.98	21.54	18.18	19.40	19.26	23.71	3.77
T3	29.30	28.07	28.16	27.79	27.14	25.64	23.13	22.19	21.07	21.26	17.81	19.77	18.93	23.87	3.99
							SD								
T1	0.70	0.30	0.31	0.28	0.35	0.60	0.35	0.45	0.31	0.98	0.64	0.84	0.25		
T2	0.62	0.39	0.58	0.31	0.25	0.27	0.29	0.45	0.68	0.32	0.43	0.76	0.46		
T3	0.70	0.79	0.60	0.46	0.37	0.43	0.94	0.86	0.94	0.66	0.45	0.86	0.15		

Annex-Ib: Fortnightly variation of average dissolved oxygen in different treatments during the study period.

Treatments	31-Aug	15-Sep	1-Oct	15-Oct	1-Nov	15-Nov	1-Dec	15-Dec	1-Jan	15-Jan	1-Feb	15-Feb	1-Mar	Average	SD
T1	7.25	7.46	6.81	6.53	6.53	6.76	6.34	7.69	6.34	6.39	6.62	7.27	7.26	6.87	0.46
T2	7.20	6.76	7.37	5.69	5.69	6.62	5.78	6.96	6.06	6.12	6.77	7.46	7.36	6.60	0.67
T3	5.40	7.09	5.83	5.78	5.78	6.34	6.99	6.40	5.80	6.43	6.88	7.55	7.52	6.45	0.71
							SD								
T1	0.13	0.15	0.09	0.11	0.18	0.13	0.12	0.14	0.15	0.15	0.16	0.14	0.13		
T2	0.10	0.43	0.10	0.07	0.08	0.06	0.08	0.24	0.15	0.08	0.07	0.12	0.08		
T3	0.26	0.13	0.06	0.07	0.10	0.05	0.17	0.14	0.05	0.10	0.07	0.08	0.08		

Annex-Ic: Fortnightly variation of average pH in different treatments during the study period.

Treatments	31-Aug	15-Sep	1-Oct	15-Oct	1-Nov	15-Nov	1-Dec	15-Dec	1-Jan	15-Jan	1-Feb	15-Feb	1-Mar	Average	SD
T1	7.50	6.15	6.73	7.18	6.53	6.98	6.34	6.32	6.27	6.35	6.62	6.99	7.03	6.69	0.41
T2	7.80	6.99	6.62	7.11	7.28	7.20	6.15	6.35	6.27	6.53	6.71	6.79	6.77	6.81	0.46
T3	7.00	6.73	6.92	6.99	6.92	6.88	5.78	5.60	6.16	6.43	6.76	6.83	6.73	6.59	0.47
							SD								
T1	0.22	0.05	0.06	0.13	0.16	0.20	0.15	0.09	0.11	0.18	0.07	0.28	0.12		
T2	0.10	0.36	0.17	0.18	0.08	0.17	0.12	0.22	0.06	0.19	0.13	0.10	0.08		
T3	0.13	0.24	0.23	0.18	0.16	0.11	0.16	0.21	0.11	0.16	0.08	0.07	0.03		

Annex-II: Fortnightly variation of average weight (g) of fishes in different treatments during the study period.

	Body weight (g)												
Species	Initial	15-Sep	1-Oct	15-Oct	1-Nov	15-Nov	1-Dec	15-Dec	1-Jan	15-Jan	1-Feb	15-Feb	1-Mar
T1													
Rohu	9.7	18.02	30.27	47.49	66.00	82.34	100.34	120.37	139.58	150.83	161.69	169.01	184.16
Catla	14.8	28.24	49.78	84.06	118.51	150.80	176.23	193.78	211.15	223.94	235.59	247.48	264.71
Mrigal	8.9	16.62	27.46	40.06	56.08	68.71	84.42	102.11	117.39	131.55	142.33	152.91	164.91
Silver carp	14.1	27.04	48.81	80.47	114.25	146.62	181.60	217.85	235.19	247.10	260.83	273.75	288.97
Grass carp	11.1	20.40	32.08	43.91	58.82	76.18	97.40	123.66	134.74	144.25	157.52	165.79	177.81
T2													
Rohu	9.8	18.40	32.44	50.25	68.32	86.77	102.17	117.73	127.69	136.71	145.18	154.04	167.38
Catla	14.5	27.66	49.05	84.79	120.38	152.16	173.25	189.41	203.77	214.39	224.08	234.05	250.34
Mrigal	8.7	16.34	29.97	43.12	57.77	68.89	79.40	90.79	97.92	104.14	110.16	115.73	124.22
Silver carp	14.2	27.23	41.12	71.91	113.60	148.82	173.60	195.40	209.06	221.60	233.70	245.62	260.73
Thai pangus	6.6	12.00	18.84	27.48	39.83	53.38	63.98	74.83	81.20	87.09	91.53	95.92	101.17
T3													
Rohu	9.8	17.91	29.38	44.61	64.50	76.76	94.18	108.07	123.16	134.42	145.44	155.91	170.19
Catla	14.6	28.42	52.57	86.15	119.94	147.10	172.64	194.82	216.70	229.83	239.67	249.28	264.81
Mrigal	8.8	16.35	25.38	38.16	50.50	64.41	73.79	81.99	90.52	95.45	99.76	103.86	110.05
Grass carp	10.8	19.74	32.22	42.57	57.75	71.69	82.66	92.49	101.83	107.12	112.39	117.14	123.79
Thai pangus	6.5	11.61	17.89	28.30	38.09	47.45	58.49	70.53	78.14	85.61	90.51	94.93	100.86

Annex-III: Survival rate (%), gross and net Production (kg/ha) in different treatments in the study period.

Treatments	Species	Stocking no./ha	Weight (g)			Survival rate (%)	Production (kg/ha)	
			Initial	Final	Net increase		Gross	Net
T1	Rohu	3125	9.7	184.16	174.46	85.35	491.18	465.31
	Catla	1875	14.8	264.71	249.91	81.29	403.46	380.91
	Mrigal	1875	8.9	164.91	156.01	77.87	240.78	227.79
	Silver carp	2500	14.1	288.97	274.87	77.25	558.06	530.83
	Grass carp	1875	11.1	177.81	166.71	81.64	272.19	255.20
Total						**80.68**	**1965.68**	**1860.03**
T2	Rohu	3125	9.8	167.38	157.58	78.56	410.92	386.86
	Catla	1875	14.5	250.34	235.84	81.29	381.57	359.47
	Mrigal	1875	8.7	124.22	115.52	71.47	166.46	154.80
	Silver carp	2500	14.2	260.73	246.53	84.88	553.26	523.13
	Thai pangus	1875	6.6	101.17	94.57	67.24	127.55	119.23
Total						**76.69**	**1639.76**	**1543.49**
T3	Rohu	3125	9.8	170.19	160.39	78.55	417.77	393.72
	Catla	1875	14.6	264.81	250.21	79.12	392.85	371.19
	Mrigal	1875	8.8	110.05	101.25	69.18	142.75	131.34
	Grass carp	2500	10.8	123.79	112.99	70.85	219.27	200.14
	Thai pangus	1875	6.5	100.86	94.36	67.24	127.16	118.96
Total						**72.99**	**1299.80**	**1215.35**

Annex-IVa: Benefit cost analysis in different treatments in study period

Species	Stocking density (no./ha)	Fry cost (Tk./Piece)	Total fry cost (Tk./ha)	Gross production (kg/ha)	Selling price (Tk./kg)	Gross income (Tk./kg)
T1						
Rohu	3125	1.00	3125.00	491.18	39.50	19401.58
Catla	1875	1.00	1875.00	424.06	34.75	14736.13
Mrigal	1875	1.00	1875.00	240.78	40.00	9631.31
Silver carp	2500	0.80	2000.00	533.33	24.00	12799.92
Grass carp	1875	0.80	1500.00	272.19	28.00	7621.32
Total			10375.00	1961.54		64190.25
T2						
Species	Stocking density (no./ha)	Fry cost (Tk./Piece)	Total fry cost (Tk./ha)	Gross production (kg/ha)	Selling price (Tk./kg)	Gross income (Tk./kg)
Rohu	3125	1.00	3125.00	410.92	38.75	15923.18
Catla	1875	1.00	1875.00	381.57	34.75	13259.43
Mrigal	1875	1.00	1875.00	166.46	38.00	6325.58
Silver carp	2500	0.80	2000.00	553.26	24.00	13278.29
Thai pangus	1875	1.25	2343.75	127.55	40.00	5101.87
Total			11218.75	1639.76		53888.36
T3						
Species	Stocking density (no./ha)	Fry cost (Tk./Piece)	Total fry cost (Tk./ha)	Gross production (kg/ha)	Selling price (Tk./kg)	Gross income (Tk./kg)
Rohu	3125	1.00	3125.00	417.77	38.75	16188.73
Catla	1875	1.00	1875.00	392.85	34.75	13651.40
Mrigal	1875	1.00	1875.00	142.75	38.00	5424.60
Grass carp	2500	0.80	2000.00	219.27	26.75	5865.49
Thai pangus	1875	1.25	2343.75	127.16	40.00	5086.32
Total			11218.75	1299.80		46216.54

Annex-IVb: Benefit cost analysis in different treatments in study period

Characters	T1	T2	T3
Fertilizer+Lime (Tk./ha)	6039.00	6039.00	6039.00
Feed (Tk./ha)	9632.00	9632.00	9632.00
Fry (Tk.)	10375.00	11218.75	11218.75
Miscellanies (Tk.)	1500.00	1500.00	1500.00
Total cost (Tk./ha)	27546.00	28389.75	28389.75
Total yield (kg/ha)	1961.54	1639.76	1299.80
Gross income (Tk./ha)	64190.25	53888.36	46216.54
Net income (Tk./ha)	36644.25	25498.61	17826.79
Rate of return %	233.03	189.82	162.79
Benefit Cost Ratio	2.33	1.90	1.63