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Water retention capacity build up of fish ponds in North-West region of Bangladesh

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WATER RETENTION CAPACITY BUILD UP OF FISH PONDS IN NORTH-WEST REGION OF BANGLADESH

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Dedicated To

My Lovely Son

Adhiraj Chowdhury Nihit

ড. মোঃ ইসতিয়াক হোসেন
অধ্যাপক
ফিশারীজ বিভাগ
রাজশাহী বিশ্ববিদ্যালয়
রাজশাহী-৬২০৫
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CERTIFICATE

This is to certify that the dissertation entitled " Water retention capacity build up of fish ponds in North-West region of Bangladesh” submitted by the candidate, Roll No. 14609, Regi. 3061,Session: 2014-2015, is the results of her own investigation who worked under my supervision as a Phd. Fellow of Department of Fisheries University of Rajshahi.

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The Author

A research work on "Water Retention Capacity build up in North-West region of Bangladesh" was done from August 2015 to March 2019 at Paba Upazilla (Rajshahi University Campus area), Charghat upazilla and Bogura Sadar Upazilla. The main purpose of the research was to increase water retention capacity as well as improve fish production, monitor water quality and growth performance. Water retention capacity and production was improved by three different techniques viz. (i) digging and polythene lining with clay soil, (ii) digging and compost layering and (iii) only digging. Water quality and growth performance was monitored fortnightly with hackit box (DR-2010, USA), net, electric balance and scale. To set up experiment a total of 27 seasonal ponds in three locations (9 at Rajshahi University campus, 9 at Charghat-Bhagha and 9 at Bogra Sadar) were selected. The selected seasonal ponds are being dug at the level of 10 feet. Then all the prepared model ponds are being maintained 8 feet, 7 feet and 6 feet of water level for the treatmentsT_1, T_2 and T_3 respectively in each site. To see the water retention capacity of constructed or re-excavated model ponds, fluctuations in water depths were recorded daily. Five farmer's practiced ponds from each location were selected as control pond. During 1st year experiment (2017), 80 fingerlings/decimal and in 2nd year (2018) 61 fingerlings/decimal were stocked with similar species composition. The variable for all ponds was water depth of 8, 7 and 6 feet as same as previous year and were considered as $Treatment_1$ (T_1), $Treatment_2$ (T_2) and $Treatment_3$ (T_3) respectively. Feeds were given twice daily with commercial fish feed at 4% total biomass rate. Pond water depth of was recorded everyday using scaled PVC pipe fixed in pond. Growth of fish was monitored fortnightly. During the first experiment in 2017**,** water depth was found above 3 feet in five seasonal controlled ponds for 6 months in Paba (RU campus) upazila, 3 feet on an average period of 5 months at Charghat Upazilla and Bogura sadar Upazilla. Whereas model ponds lengthened round the year and the highest average water depths were 6.43 feet in T_1 at Paba upazilla, 5.47 feet in T_1 for 6 to 8 months at Charghat upazilla and in Bogura sadar Upazila 7.00 feet at T_1 for the year round. In this experiment the mean water quality parameters both physical and chemical parameters were in the suitable range where there was no significant ($p>0.05$) difference in temperature, transparency, pH, DO and CO_2 among the treatments. The harvesting period was in December. The highest specific growth rate (SGR) 1.33% was found in Paba and Charghat. The highest food conversion ratio (FCR) 0.66 was in Bogura. In Paba upazilla net production was 16.04, 17.2 and 15.01 Kg/d for $T_{1,}$ T_2 and T_3

respectively whereas average 4.35 kg/decimal was in the controlled pond which was 268.74%, 295.40% and 245.06% increased for T_1, T_2 and T_3 respectively . In Charghat net production was 14.79, 18.6 and 18.44 Kg/ d for T_1, T_2 and T_3 respectively whereas 4.32 kg/d for control pond which was 112.74%, 178.86% and 176.46% higher. At Bogura sadar upazila the net production was 12.85, 12.72 and 12.7 Kg/ d for T_1, T_2 and T_3 respectively and for control pond it was 5.14 kg/d which was 186.23%, 183.09% and 182.61% higher. During second experiment in 2018, the highest mean water depth in model ponds were found in Paba and Charghat (5 feet) where control pond have 2 feet. In Bogura Sadar upazila the highest water depth was found 4.29±0.63 foot for round the year in the model ponds whereas 2.39 feet for the controlled pond. The physical and chemical parameters were found in the suitable range where there was no significant ($p>0.05$) difference in temperature, transparency, pH, DO and CO_2 among the treatments. The initial weight of fish fry was 3.08±0.004, 3.09±0.01 and 3.10±0.01 for Paba, Charghat and Bogura Sadar respectively. The Specific Growth Rate (SGR) was found highest in Paba (2.35%) and Food conversion ratio (FCR) was also highest (1.47) in Paba. Average fish production of five control ponds was found highest in Bogura 5.28 kg/decimal in the study period whereas at the same time the bottom layered polythene based model ponds at Rajshahi university area production yielded 253.02 higher against the control ponds. The average net production was more than 3 times better in model ponds than the controlled ponds. Maximum net production was found in polythene based model ponds at Paba upazila due to increase water holding capacity of ponds and scientific fish culture techniques. Farmers have been benefited more than past and the social acceptance of the research findings have been increased by the society tremendously.

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Chapter - 1

INTRODUCTION

Among the agricultural sub-sectors fisheries is one of the major who dose a vital fundamental act in the social and economical improvement of rural people, supplying the animal protein, increasing job sectors, poverty alleviation and increasing country's remittance and also foreign exchange. According to DoF 2020 in the 2018-19 fiscal year total production of our country was 43.84 million metric ton in which 37.24 million metric ton came from inland water and 6.5 million metric ton came from coastal water, and 3985.15 crore taka of foreign exchange earning of Bangladesh comes from the fisheries sector. 3.50% of total GDP and 25.72% of agricultural resources Fisheries sector showed strong performance on GDP at 4 % average annual rate in 1990 (CPD, 2002). Life and livelihood of the Bangladeshi people is mostly depended on fisheries sector (Ahmed, 2001). Protein intake has been decreasing day by day but still 63% of animal protein comes from fish and fisheries (Ahmed and Rahman, 2005). 80% consumed fish were harvested from natural sources during 1960 to 1970 (Ahmed and Rahman 2005). Because of the over fishing for the over population of the country and change of environment the natural stocks has declined upto 34% 2005 and thus the fish culture has increased in large numbers in close water in the last twenty years (ADB, 2005). In Bangladesh the main source of protein, vitamins and micronutrients are Fishes (Thilsted et al.1997).

Climate changes (temperature, rainfall, hydrology etc.) directly affect the agricultural (crops, fisheries, and livestock) production (Ficke et al. 2007). Renowned organization World Fish Centre surveyed in Asia and found some tropical countries like Bangladesh, Cambodia, Pakistan and Yemen are the most vulnerable depending on the vulnerability of national income to the impacts of climate change on fisheries (Allison et al. 2005). In aquatic production global climate change has adverse affect. For example, lack of rainfall may be a reason of water unavailability which causes droughts to little flood or no flood which will decrease the water quality (IPCC, 2007). However, the effects of climate changes in the North western Bangladesh on fisheries resources especially on aquaculture are more serious.

From rainfall data analysis (1960 to 2010) of Ferdous and Baten, 2012, the annual average rainfall showed a decreasing trend of 3.0698 mm/year in the North-west regions of Bangladesh with a short length of rainy season which have direct negative impact on fish culture specially on seasonal ponds. Water holding capacity of soil is one of the factors in the North-west part of Bangladesh, where fifty five percent of the seasonal are not suitable for fish culture in December to May as low water retention capacities of bottom layer. Changes in rainfall have been causing a spectrum of changes in water availability in the region. Poor water holding capacity of bottom soil of seasonal ponds, lack of technological knowledge and technology adaptation of fish culture in rural areas are great problems, as have been found in respect of fish production in Rajshahi side of Bangladesh (Islam and Haque 2010).

Bangladesh is a country with hundreds of rivers and ponds. Pond fish culture is the fundament of Bangladesh aquaculture and it produces 85.8% of total production and covers 57.7% area (DOF, 2010). There are nearly 13 lakh ponds in the country which area was 1 lakh 51 thousand ha. 55% is cultured, 29% might be culturable and 16% is currently not cultured but can take under profitable fish culture. In the year of 2002 72%, 20% and 8% production was found from those three systems (BBS, 2004). In Bangladesh there are two types of pond found one is perennial and another is seasonal ponds (Islam and Haque, 2010). Simplistically a perennial water body is one that keeps full or flowing throughout the year or which carry water all the year round and seasonal ponds are those which contain water about 5-6 months of the year. Conventional fish farming in seasonal ponds in our country is based on fish polyculture of mainly carp fishes in ponds and ditches. Trends in many of the drivers of demand indicate that aquaculture will continue to expand where seasonal pond has great opportunities. In the North-western region of Bangladesh 55% of ponds are seasonal and 45 % of are perennial ponds and the pond size is average 0.09 ha (Islam and Haque, 2010). Water holding capacities of the pond become lower day by day so the number of seasonal pond is increasing in the northern districts of Bangladesh. In our country about 60% of total seasonal ponds retained water for 4 to6 months while 40% retained for 6 to 9 months in a year and even more in some areas (BBS, 2004). These seasonal water resources are mainly used for household chore but some are still not used because of their derelict and marshy nature. From the findings of DoF, 2009 55% of total inland fish production comes from aquaculture where only 11% of the total resources were used. Over the last thirty years, aquaculture established as the fastest growing food and also rich protein producing sector in the world which reduce poverty. DoF, 2010 declared that the total 2.7 million fishes were produced in Bangladesh where 2.7 million MT comes from aquaculture and this contribution was 2.1 million MT in 2009. This production is also added with global production and to continue this increasing order of aquaculture production, upto 65.1 million MT production target was set in 2030 in the world (Verdegem et al., 2006). Seasonal rains are the main source of water of the seasonal ponds and the water depth depends on some factors such as the amount of rainfall, intensity of evaporation, seepage and the water retention capacity of the water body. When the monsoon ceases, the water level starts getting low and at the last of the dry season the water level is at its minimum. Fish biomass has direct relation with water depth. Fish biomass attains its maximum size when the water level is maximum. Most of the carp culture ponds cannot be drained by pumps or other mechanical devices. They deposited large amount of silt that create unfavorable conditions for fish culture. In home stead seasonal ponds short-cycle species like Silver carp, glass carp, tilapia, nilotika etc. were cultured. These types of seasonal ponds were formed due to borrowing of soil for house or road construction or for household uses like bathing, washing or for irrigation. These short-cycle fish species can be used for pond aquaculture where water retains for only 3 to 4 months. The culture technique is very friendly that can be practiced by women and children. It is requiring very low labour and input. Production is used for household consumption and also for market. Rajshahi region is famous for carp culture but there are some constraints which hamper in sufficient production. The constraints hamper fish production in different ways such as lack of input which resulting fewer yields, financial problems causes insufficient cultural intensity, little adoption of new technology resulting lower culture environment and nonsatisfied fish growth etc. Lack of training and illiteracy of farmer affects the carp production. Carp production for trained farmer's pond is 47% higher than non trained farmer pond. There found a clear difference in average yield of educated and non or lower educated carp farmers. Beside these the water retention capacity of the soil of Rajshahi district is very low in dry season. Large number of pond becomes unsuitable for fish culture in the time of dry season for lacking of water. Most of the fish farmers were harmed by little or no water depth and also seasonal drought.

This research was planning to develop a model for more improved semi-intensive fish culture using less water by increasing water holding capacity considering emerging climate changes in the North West Bangladesh. Success of this research model will be help in stable development which is environment friendly, technically accurate and good for economy and socially appreciable in the NW Bangladesh. In Rajshahi region, small water harvesting ponds with polythene on the bottom of the ponds under different depths are new technique for fish culture. This system is very useful water harvesting structure on the inherent topographic features and hole of the ponds. These seasonal ponds are generally filled with water from the rain water or using deep tube well. For providing stability to the small water harvesting tanks, the polythene layer under different depths are usually made with market available polythene from the bottom level and covered clay soil of pond base. The stored water is utilized for fish culture, which are grown extensively in the region. Fisheries sector improves the rural socio-economic status which is hampered by climate change and it affects in production, human health and also in physical assets. Rajshahi region is declared as the most output zones in agriculture and aquaculture production because of drought prawn area. Moreover the soil type and water scarcity and climate change issues leads the farmers of this region more vulnerable as compared to other region of the country.

The northern part is characterized by the data of high temperature and low rainfall compare to other region of Bangladesh. During dry season water level of these seasonal ponds decreased because of low water retention capacities of sandy soil which become totally unsuitable for fish culture. High temperatures, high evaporation rate and rainfall patterns change are the reasons of drought situation in Northern region of Bangladesh. Moreover the country is forecasted on yearly average rising temperatures of 1°C at 2030, 1.4°C at 2050 and 2.4°C at 2100 (IPCC, 2007). UNDP (2008) reported that the country faced high temperatures specially the month of April to August over the last thirty years. Winter season prediction represents almost same rising pattern of mean temperature of 1.1°C in 2030, 1.6°C in 2050 and 2.7°C in 2100. While the projected value is 0.8°C in 2030, 1.1°C in 2050 and 1.9°C in 2100 for the summer (Agrawala et al., 2003; Ahmed, 2006). Furthermore the average evaporation data follow the upbringing trends in all over the Rajshahi division by 0.50 mm/year (Ferdous and Baten, 2012). From rainfall data analysis of 1960 to 2010

(Ferdous and Baten, 2012), the annual average rainfall showed a decreasing trend in the NW regions of Bangladesh as 3.0698 mm/year which showed that length of rainy season is decreasing which have direct negative impact on fish culture in this region specially on the seasonal ponds.

If ponds are shallow, the stocking capacity must be limited ultimately production is low. Shallow ponds mean that the water holding area is low and the pond is suspected to dry out and these limit the production period. This particular problem is for the country such as ours where a huge amount of ponds are rain-fed (Kunda et al. 2008). Depth of fish culture ponds must be sufficient enough for temperature demands and also other habitat requirements of rearing fish. Despite the specturm effects of pond depth on fish growth and survival, adequate information is not available on this matter. For tropical and subtropical regions 1 m depth is suitable for carp culture (Pillay 1990). Fish production in Bangladesh especially Northwestern region of Bangladesh has faced a tremendous problem. This region is severe drought-prone area in Bangladesh and drought may come frequently and intense along with horizontal expansion due to climate change. Agriculture as well as farmer’s livelihood is badly affected due to the effect of drought.

Lack of technological knowledge is a vital problem of carp culture in seasonal ponds in rural area of this country. About 18% farmers do not know about the modern technological knowledge of carp culture (Islam and Dewan, 1986) and surprisingly they are not interested in all that.

Fingerlings are stocked by farmers in their resources in the month of May to June when there is plenty of water in the seasonal ponds. During December to May, low water is available for fish culture and many ponds dry up finally the production became low due to short culture period. Water holding capacity in seasonal ponds is primarily depend on soil texture and organic matter of the bottom of the pond. Soil of small size particles like silt and clay contain a larger surface area in comparison with large size sand particles. Large surface area of sand particles allows soil to hold more water. Soil of high percentage silt and clay, which calls fine soil, has higher water holding capacity and good for fish culture. Water retention capacity is influenced by soil texture and organic matter percentage of the bottom of the country. As an alternative, sustainable aquaculture technique is needed to be developed which can mitigate the loss of production and thus sustain the required fish production in our country.

Based on the above problematic condition the research was planned with the following objectives:

Objectives

The precise objectives are as follows:

1. To increase the water retention capacity of seasonal ponds under three upazillas.
2. To estimate the growth performance of fish species under the model ponds
3. To know the water quality of the research ponds.

Some amazing changes in drought porn areas will depend on the success of this research work. Positive results of this research work can convert seasonal ponds into perennial pond and also will increase-

- Water retention capacity of ponds
- Culture period
- Production
- Ultimate profit
- Social status of marginal fish farmers

Chapter - 2

REVIEW OF LITERATURE

Before introducing an experiment it is necessary to know the information about previous related works. In the present review, attempts have been made to gather information available about relevant to present research work.

2.1 Growth performance of fish farming

Ghozlan et al. (2018) carried out a study on Nile tilapia (*Oreochromis niloticus*) in 9 ponds under 3 treatments. His findings were on the impact of water source on some important parameter like survival rate of fish, growth curve, food conversion ratio, fish yield, economic aspects and production data. The average sizes of all ponds were almost 5200 square meter. All male monosex Nile tilapia were stocked at a period for 192 days. The weight of fish fingerlings was 4.38±0.03g. Supplementary feed was given every day at 3% rate of fish weight by floating feed having 25% protein crude. From the findings it was showed that body weight was increased significantly ($P<0.05$). Survival rate was 98.53%. Production was 2128kg at freshwater, 1921.8 kg in drainage water and 2837.7kg at well water.

Rahman *et al.* (2017) studied on the growth of fish, production status and economical aspects in polyculture of three Indian major carps viz. *Labeo rohita* (Rui), *Catla catla* (Catla) and *Cirrhinas mrigala* (Mrigala) and three exotic carps like *Hypophthalmichthys molitrix* (Silver Carp), *Ctenopharyngodon idella* (Bighead Carp) and *Cyprinus carpio* (Common Carp). He worked on two types of experimental design like fertilizer used and supplementary feed given for 6 months long from April, 2009 to September, 2009 at Nischintopur village at Bagha Upazila of Rajshahi district. Two treatments viz. T_1 urea+TSP+cowdung+poultry droppings and T_2 rice bran (30%)+mustard oil cake (25%)+fish meal (10%)+maize bran (35%) at the rate of 3-5% of the body weight per day were designed with three replications. 5000 fingerlings in 1 hectare with the ratio of 5:2:3:8:3:1 were stocked in each treatments. Different water quality parameters (water temperature, transparency, DO, free CO_2, pH) were found in range. The highest growth rate of fishes was in T_2. Significant differences of production were found in T_1 and T_2 (2360 kg/ha in T_1 and 4022.5 kg/ha in T_2).

Basak *et al.* (2017) compared different carps in various stocking rates in polyculture system.3 treatments with 3 replicates were designed like 80 (rui 30+ catla 30+ mrigal 20), 70 (25+25+20) and 60 (25+20+15) per decimal in T_1, T_2 and T_3 respectively.

Results showed that the highest weight was 622.50±293.50g in T_3 of Catla, followed by Rui (572.40±153.90 g) and Mrigal (532.0±117.54 g) and the lowest was in T_1 for all species. The highest SGR was in T_3 for Rui (1.22±0.03) and the lowest in T_1 for Catla (0.89±0.04). The highest production was in T_1 (4623 kg/ha/10months). In T_2 it was 4465 kg/ha/10 months and T_3 was 4643 kg/ha/10 months). The highest survival rate was found in treatment 3.

Rumpa *et al*. (2016) researched on the growth related parameters and production variation of various carps including *Labeo rohita*, *Catla catla*, *Cirrhinus cirrhosus* and *Cyprinus carpio* in shaded ponds at Barisal. 5 heavily shaded ponds (HSP) were used as T_1 and 4 moderately shaded ponds (MSP) treated as T_2. The average area of HSP was 0.03±0.01ha and MSP was 0.07±0.03 ha. The experimental period was of 6 months from July to December of 2013. Carps stocking rate was 14820/ha and the ratio of Rui, Catla, Mrigala and Common carp was 2:1:2:1. Carps were fed by rice bran, wheat bran and mustard oilcake at the rate of 10% body weight for first 3 months and 5% body weight for last 3 months. The highest weight gained was in common carp (467.00±0.00 g) in T_1 and the lowest was in mrigal (172.46±26.80g) in T_1. Production was high in T_2 (2122.92±333.60 kg/ha/year).

Haque *et al*. (2015) conducted an experiment comparing the performances of various carps i.e. *Labeo rohita*, *Catla catla*, *Cirrhinus cirrhosus* and *Hypophthalmicthys molitrix* in various stocking densities of polyculture in aquaculture system. 3 treatments with 3 replications were set up and stocking densities were 40, 80 and 160 per decimal in T_1, T_2 and T_3 respectively. They found the highest weight was 176.33±15.76 g in T_1 by silver carp and the highest length was obtained in T_1 by rohu at 13.07±0.59 cm. Percentage of the highest SGR was in T_1 for silver carp (2.87±0.03) and the lowest was in T_3 for catla (1.51±0.06). The highest production was in T_2 (2747.47±116.47 kg/ha/year). From the results we can saw that the stocking density of 80 fingerlings per decimal (T_2) is the most suitable for higher production in polyculture.

Sarker et al. (2014) conducted an experiment in 6 homestead ponds, area of 20 decimal to find growth parameters and production of fishes in polyculture of tilapia (*Oreochromis niloticus*), silver carp (*Hypophthalmichthys molitrix*), catla (*Catla catla*), rohu (*Labeo rohita*), mrigal (*Cirrhinus cirrhosus*) and mirror carp (*Cyprinus carpio var. specularis*) for 121 days from March to June, 2012 at Gouripur upazila, Mymensingh. Experiment was designed by 3 treatments each of 2 replicates. The highest mean final weight among three treatments of tilapia, silver carp, catla, ruhu, mrigal and mirror carp were 154.8, 258.8, 119.7, 119.7, 124.7 and 193.8 g in T_3 respectively.

Hossain *et al.* (2014) find out how growth and production of carps fries (Silver carp, Mirror carp and Rui) were effected by fish population density in pond polyculture for a period of 3 months. Average stocking weight of the individual fry of silver carp, mirror carp and rui were 0.10g, 0.103g and 0.08g respectively under T_1 and T_2 0.17g, 0.142g and 0.11g respectively. Balanced feed including inorganic and supplementary (50% per body weight) was used to all treatments. Silver carp's survival rate was 38.60% and 66.48%, mirror carp was 31.20% and 45.50% and 31.51% and 53.35% for Rui in T_1 and T_2 respectively. The net fish production of T_1 was 1905.13±141.95 kg/ha/90d and 3831.74±411.35 kg/ha/90d in T_2. Results revealed that net production and growth performance was better in T_2 than T_1.

Hosen *et al.* (2014) conducted a research on changes of growth and production in polyculture system on using artificial feeds. Indian major carp (*C. cirrhosus*) and exotic fishes (*H. molitrix* and *O. niloticus*) were stocked in 6 ponds under 2 treatments and 3 replications each. At 2:2:1(silver carp: tilapia: mrigala) 100 fish/decimal were stocked in both treatments. Both fertilizer and supplementary feeds were given in T_1 and only fertilizer was given in T_2. Gross and net production was 16.56 and 12.48 ton/ha respectively in T_1 and 9.99 and 5.91 ton/ha respectively in T_2. Production was 2 times better in T_1than T_2 .It declared that feeding is important in pond aquaculture.

Pravakar *et al*. (2013) surveyed on fish polyculture, social status and economical aspects of fish farmer in the Shahrasti Upazila, Bangladesh from February to September, 2010. Pond size was average 0.24 ha in this research. 85% of the farmers had ponds of their own. Carps were mainly cultured in 10% seasonal ponds and 90% perennial ponds. Average yield of fish was found to be2900 kg/ha/yr.

Ali *et al.* (2008) surveyed on the social status and economical condition of farmers in Hamirkutsha and Kamarbari Unions of Bagmara upazilla, Rajshahi. Average Ponds were 0.13 ha in average size. Most of the ponds were in single ownerships (64%) and 36% was multiple ownerships. Average yearly return of most of fish farmers were above Tk. 75,000 per ha. The major constraints were lack of scientific knowledge, money and multiple ownerships.

Tanjeena *et al.* (2007) studied in Mohanpur Upazilan of Rajshahi district on the ponds as fishery resources and the socio-economic conditions of fish farmers. Pond sizes of the study area ranged from 15 to 180 decimal. Almost 57.8% ponds were single ownership. She concluded that 65.5% were fish culture ponds, whereas 28.5% were culturable and 6% were not used.

Alam (2006) assessed the livelihood status of farmers in Mithapuqur Upazila, Rangpur. The average pond size was more or less 0.15 ha. Among the ponds 32% were seasonal and others were perennial ponds. He found that most of the ponds (80%) single ownership others were multi ownership. The stocking density was 17,262 fry/ha/year and annual net production was 2,609 kg/ha/year. The cost benefit ratio was calculated1.81.

Rahman *et al.* (2006) conducted a study on culture potential of *Barbodes gonionotus* (Bleeker) (Thai Sharpunti) and major carps in seasonal ponds. Major carps were rohu (*Labeo rohita*), catla (*Catla catla*), mrigala (*Cirrhinus mrigala*) and silver carp (*Hypophthalmichthys molitrix*).He studied for three months. Three treatments with different stocking densities were designed with three replications each. The total production was 1,248.34 kg/ha in T_1, 343.19 kg/ha in T_2 and 1,592.67 kg/ha in T_3.

Islam (2005) surveyed on social and economical situation of farmers in Dinajpur. In this study area pond size was more or less 0.16 ha or 40 decimals. During study period it was found that seasonal ponds were 60% and rests were perennial. Ponds of 76% farmers had single ownership and 24% multi ownership. Farmers stocked fish from March to May and average stocking density was 17, 370 fry/ha/year.

Paul (2005) studied on fingerlings rearing profitably in Netrokona district. He calculated per hector gross cost for fingerlings was Tk. 142827 while gross return and net return per hector were Tk. 275123 and Tk. 132295 respectively.

Roy (2004) studied on the social and economical aspect of carp culture farming in Kurigram District. He found that 6% of the fish farmers cultured exotic carp, 14% Indian major carps. He also resulted that average fish production was 3,797.5kg/ha while in Kurigram sadar and Nageswari were 3,675 kg/ha and 3,920 kg/ha, respectively.

Saha (2004) surveyed on aquaculture technology in Tangail and found the pond size was 0.19 ha in average. Three types of ponds were found like ponds were seasonal (37%), homestead (74.5%) and multiple ownership (21%). The average stocking density was 17,419 fry/ha. The average gross fish production was 2,890 kg/ha/yr.

Ahmed (2003) studied on yield gaps, loss in production and profitability of pond fish culture in Netrokona. The average annual per hector fish production were 4655 kg in individual owned farms and 2409 kg in multiple ownership farms. Feed, human labor, fingerlings, lime, fertilizer had positive and significant impact on pond fish production. Yield gaps was substantial 1527 kg /ha and production loss was estimated 63,06 kg/ha. The major problems were lack of sufficient money, low fish price during selling and high input (feed, fertilizer, fingerling cost, labour etc.) prices.

Saha (2003) researched on fish culture in Dinajpur and got the pond size was 0.21 ha in average. Three types of ponds were found viz. seasonal (17%), perennial (83%) and multiple (14.5%) ownership. The stocking density was 16,561 fry/ha in average. Supplementary feed (rice-bran 1,407 kg/ha/yr, mustard oil-cake 793 kg/ha/yr, and poultry manure1,936 kg/ha/yr) were commonly used.

Rahman (2003) researched on carp culture system in Gazipur district and found most of the farmers (90%) cultured both Indian major carps and exotic carps. He found the pond size was 0.12 ha in average and the stocking density was 25,250/ha. The average annual yield of carp was 2,925 kg/ha/yr.

Alam *et al.* (2002) studied on carp polyculture of over-wintered fingerlings under different stocking densities. An on-farm trial of twelve earthen ponds (1200-1600 m') was undertaken to evaluate the growth and production of over-wintered fingerlings. Used fingerlings were from rohu (*Labeo rohita*), catla (*Catla catla*) and mrigal (*Cirrhinus rnrigala*). In this polyculture system three different stocking densities were used. The stocking densities were 2,250; 3,250 and 4,250 fish/ha in T_1, T_2, T_3 respectively. Fishes were fed with rice bran and mustard oil cake at 3:1 ratio. Fish production found in T_1, T_2, T_3 were 2325±74.75, 2620±49.66 and 2982±171.52 kg/ha respectively. T_1 had the higher mean growth.

Robbani (2002) surveyed in Mymensingh, Jessore and Laxmipur region. Carp production was half tons/acre/year. Many constraints were identified like inbreeding, insufficient quality seed, shortage of technical knowledge on scientific fish culture, fish disease, marketing, multiple ownership and scarcity of quality feed etc.

Alam and Thomson (2001) worked on the culture situation of fisheries in Bangladesh They worked on the entire major sub sector, namely inland open waters, inland closed water aquaculture and marine fisheries. There were many constrains on culture and it was difficult to identify significant achievement from government policy effort.

Biswas (2001) found during his study period that the average cost of fish production/hectare/year for Tarash and Neemgachi regions were Tk. 47.064 and Tk. 46,9777 respectively. The average annual production of fish per ha, gross income, gross margin, net return and Benefit Cost Ratio (BCR) were 2,264.50kg, Tk. 67926, Tk. 43639.50, Tk. 20905, and 0.44, respectively.

Quddus *et al.* (2000) worked in Demra, Dhaka and found on the total ponds about 34% were multi ownership, 54% single ownership and the 12% ponds were government or organizational property. About 95% of the pond owners were interested in fish culture. During monsoon only 28% ponds become flooded every year, 21% were rarely flooded and 51% ponds never flooded. Per hectare yields of extensive culture system were 1300 kg, improved extensive were 2120kg and semi-intensive were 4000 kg categories and net return were Tk. 46,000, Tk. 63,000 and Tk. 9,2000 respectively in those three systems.

Biswas *et al.* (2000) declared that aquaculture of BRAC had heavy profit. He got the average total cost of pond fish production/ha/year was Tk. 59,813.57 while gross income and net return were Tk. 14,532.67 and 85,511.10 respectively for all selected study areas.

Das A.C. (1999) conducted an experiment on polyculture of different indigenous and exotic species at different stocking densities in 16 farmer's ponds in two Thanas (Sadar and Delduar) under Tangali district in two combinations A and B (combination A, 6 speceis and combination B, 7 speceis) consisting of two treatments for a period of 305 days. The treatment differed from each other in respect of stocking density which were 30/decimal and 40/decimal in treatments I , II, III and IV respectively with four replications (two 6 species and two 7 species). In combination A. 3 exotic carps were used. In combination B. above 6 species and silver barb were used as an additional species. Fishes were fed with rice bran and mustard oil cake and rate of 2%

of the body weight daily to the fish. Significantly higher production of fish was obtained in combination A. The highest production was achieved in treatment III (6,989 kg ha-1 305 days-1).

Hossain (1999) worked on costs, returns and profit of pond fish culture. To know the relationships of major factors in fish production, he used a linear production function model. Gross return of pond fish production was Tk. 1,67,631/ha/yr. During the study period the net return was found for the small Tk. 25,224/ha, medium TK 26,060/ha and large farms 32,973/ha.

Mazid and Hussain (1999) reported that average yield of carp polyculture was nearly 1800-2000 kg/ha and by using BFRI carp polyculture technology. This production rate could be increased 4 to 5 times i.c. with technology production rate to the range of 7,000 to 10,000 kg/ha is possible.

Mahmud (1998) conducted an experiment to optimize the stocking density of Thai Sharpunti, (*P. gonionotus*) in the polyculture with Rui (*L. rohita*), Catla (*C. catla*) and Mirror carp (*C. carpio* var. *specularis*). There were three treatments and stocking rate of rohu, catla and mirror carp in all ponds was 3,300 3,300 and 3,400/ha respectively. Thai sharpunti was stocked additionally at the rate of 5,000/ha, 6,000/ha and 7,000/ha respectively. Fishes were reared by supplementary feed such as rice bran (60%) and mustard oil cake (40%) daily at the rate of 3% of biomass, and duckweed (*Lemna minor*) was also supplied to the pond at rate of 10% of the body weight of Thai sharpunti. Ponds were fertilized at an interval of 15 days throughout the experimental period with cowdung, Urea and TSP at the rate of 2,700, 100 and 100kg/ha in treatment I, 2,078.8 kg/ha in treatment 2 and 1,713.4 kg/ha in treatment 3. A significantly higher ($P<0.05$) production (2,078.8 kg/ha) was reported in treatment 2.

Hung *et al.* (1998) experimented with *P. hypophthalmus* reared in outdoors concrete tanks to study the effects of frequency and period of feeding on growth and feed utilization. The fish were fed diet containing moisture 3.10 %, protein 37.17 %, lipid 5.41 %, minerals 23.50 % and cellulose 8.96%. They concluded that in two meal feeding (7.00 & 17.00) the SGR (% day) was 3.34 and FCr 1.40 which was the best result that one meal (7.00) and three meal (7.00, 12.00 and 17.00) meal feeding.

Islam (1998) got the average hectare/year fish production of two types of fish farmers like credit and contact farmers were 4,258 kg and 3,019 kg respectively. Ha/year gross return of the credit and contact farmers were Tk. 1,47,965 and Tk. 1,05,514 respectively. Net return on the basis of full cost Tk. 61,777 and cash cost Tk. 104,585 was for credit farmers and Tk. 35,493 and Tk. 74,411 for contact farmers respectively.

Rahaman *et.al* (1998) found that fish production in ponds could be increased either by increasing the size of pond or improving the production technology in existing condition of ponds. It was found that pond fish output was influenced o a great extent by the level of culture and management practices performed. The study also revealed that the higher net return influence by price of output and economic use of both materials input and labor for pond fish production. The gross and net returns per hectare were found Tk. 96,441 and Tk. 63,123 respectively.

Hasanuzzaman (1997) conducted a research on comparative study of fish production under different management practices in some selected areas of Rajshahi district. This study was conducted mainly to determine the relative profitability of pond fish production under credit and noncredit management system in three Upazila's in Rajshahi district. The general output of the study clearly indicated that pond fish production under both credit and non-credit management system was highly profitable business.

Hossain *et al.* (1997) got the average carp production 2,133 kg/ha in 105 days in a polyculture system using supplementary feed viz. rice-bran and mustard oil-cake at 1:1 ratio and at the rate of 5% body weight. Fishes were fed daily in two times.

Kanak (1997) got the highest gross production 2,623 kg/ha/6 months in polyculture of Indian major carps, Chinese carps and *Pangasius sutchi* in ponds. Supplementary feed wheat bran (50%), mustard oil cake (45%) and fish meal (5%) were given at the rate of 3% body weight daily.

Mazid *et al.* (1997) worked on fish polyculture of Rui (20%), Mirror carp (5%) and Sarpunti (15%) at the density of 4,000/ha. Supplementary feed including rice bran (75%) and mustard oil cake (25%) were used. Both inorganic (l00 kg/ha/month) and organic fertilizers (3,000 kg/ha/month) were.

El-Sayed *et al.* (1996) reported that growth performance and survival rate was significantly related with pond depth and water temperature. He found that weight gain was lowest (250 g/fish), feed conversion ratio was poor (3.15) and mortality rate was the highest (41.5%) at 50 cm depth. On the other hand 100-200 cm pond depth and warm water temperatures (>21 °C) got the best growth. Fish growth was significantly reduced ($P<0.001$) at the temperature below 21°C. Below the temperature at 10°C, fishes stopped feeding and developed severe stress, fungal infection and high mortality. However the depth of significantly reducing mortality rate was 300 cm.

Shohag (1996) researched on fish production in Nandail thana of Mymensingh district. He surveyed on 50 ponds to know the ownership pattern, production, costs and return of pond fish culture and different constraints that affecting the production adversely. He noticed that pond fish production under supervised credit system was mainly dependent on stocking of fingerlings, use of fertilizer and artificial feed and human laborer for different issues.

Rana (1996) surveyed in 3 upazilas in Sirajgonj district. He worked on 60 ponds and found that pond aquaculture was very profitable. Rana described on his findings that pond size and stocking of fingerlings, multiple ownership affected negatively on fish culture. On the other hand feed, fertilizer and human labor had positive effect on pond fish culture. He found the major problems associated with fish production were scarcity of feed, no or less marketing facilities, lack of materials and proper technical knowledge, natural disaster like flood, disease, multi ownership, high prices of inputs and theft of fish.

Ahmed (1995) carried out an experiment on mixed culture of Mirror carp (*C. carpio*), Red tilapia (*O. nilotica*), Silver carp (*H. molitrix*) and Thai sarpunti (*P. gonionotus*) in the ratio of 1:2:2:5 for 105 days and there were six treatments with two replications and each pond was stocked with a total of 100 fish at the rate of 33,333 fish/ha. The best growth performance of mirror carp, tilapia and thai sarpunti were found by feeding rice bran plus mixture of organic and inorganic fertilizers containing 2.5 kg cowdung and 100 g Urea-TSP (1:1) applied weekly with a total production of 2,333 kg/ha.

Rahaman (1995a) studied on social and economical analysis of pond fish culture in some selected 48 stocking ponds purposively from three different upazilas namely Netrokona Sadar, Purbadhala and Kendua of Netrokona district. He found that ownership status of pond, species count and human labor negatively affected the fish production, while depth of pond water, farm size, fish seed, fertilizer and artificial seed were statistically significant in explaining the variation in fish pond out in a study area. He found that every hectare yearly fish yield was 943 kg and the average gross net returns because of using higher among of inputs compared to large farmers.

Saha *et al.* (1995) got on his findings that over fishing expenses of pond fish production/ha/year were 2,892, 3,035, 2,803 and 1,847 kg in Netrokona, Ghatail, Bhaluka and Pakundia. Net return was of Tk. 15,611, 75,028, 51,489, 23.560/ha respectively. The average rate of organic and inorganic fertilizers were 15,280 kg/ha and 432 kg/ha respectively for all ponds in all study areas. The average rate of rice-bran and oil-cake were used 5,192 and 734 kg/ha with the range of 1,025-11,780 kg/ha and 110-1,367 kg/ha, respectively.

Rahman (1995b) carried out a research in some areas of Gouripur thana of Mymensingh district. He worked on 60 ponds and resulted that the higher level of inputs used ponds gave higher outputs. He got the average annual fish production was 4,923 kg/ha and it ranges from 4,505 to 5,413 kg/ha. He found the average gross return was Tk. 72,910/ha and net return was 15,833/ha.

Kohinoor *et al.* (1994) evaluated the production and growth performance of local Sarputi (*Puntius sarana*) and Raj puti (*Puntius gonionotus*) under semi-intensive pond culture system. The ponds were used cow-dung, urea and TSP at the rate of 7,508 and 16 kg/ha respectively as fertilizer at fortnightly intervals. Rice bran were also fed twice daily to the fish 4 to 6% of their body weight. After six months, average fish production was 2,075 kg/ha for *Puntius gonionotus* as compared to 1,304 kg/ha for *Puntius sarana*.

Uddin *et al.* (1994) obtained production of polyculture of some carps of 3,415 kg ha-1 when stocking density was 4,000 fingerlings/ha. In their study, the species combination was Catla-40%, Rohu-20%, Mirror carp-5% and Rajpunti-5% and the fishes were feed with rice bran (75%) and mustard oil cake (25%) and organic manure was used at the rate of 3,000 kg/ha/month.

Mahmud and Tanu (1993) conducted research on poly culture of giant freshwater prawn with carp species (Silver carp, Catla, Rohu and Thai sarput) at Chandpur. They obtained the production of fish 4.5 ton/ha/yr and prawn 1.0 ton/ha/yr at the stocking density of 7,000 fingerlings/ha and 12,000 juveniles/ha, respectively. They also reported that the survival of carp species was fairly high and ranged from 87.1 to 96%.

Akhteruzzaman *et al.* (1991) designed an experiment on semi-intensive monoculture of native sarpunti (*Puntius sarana*) in five ponds of 360 sq. m each for five month under two treatments with supplementary feeding (rice bran) and fertilization. The stocking densities were maintained 12.500 fish ha-1. The gross average production obtained with feeding was 1.196 kg ha-1 and that with fertilization was 605 kg/ha.

Gupta *et al.* (1990) performed an experiment to study the efficiency of cow-dung with and without supplementary feed in polyculture of Indian and exotic carps. Supplementary feed i.e., rice bran and mustard oil cake (1:1) was provided at the rate of 3% of body weight per day. Production was almost double at 19.7 kg/decimal year (4,917 kg/ha/year) with supplementary feed compared to that of 10.3 kg/decimal/year (2.583 kg/ha/year) without supplementary feed.

Mollah *et al*. (1990) conducted a study on "Input output relation in fish production under various pond size, ownership pattern and constraints." The results of the study indicated that the quantities of inputs used in small ponds were higher than medium ponds followed by large ponds. The income per hectare per year was higher in smaller ponds (<0.12 ha) followed by medium ponds (>0.12 to <0.24ha). Ponds under single ownership gave higher production of fishes than the ponds under multiple ownerships.

Hannan *et al.* (1988) carried out a preliminary study on the culture of *P. pangasius* for a period of 7 months in a 1,970 m² pond at the riverine station Chandpur in Fisheries Research Institute. The stocking rate was 8700 fry/ hectare. The fish were fed on a mixed supplemental diet. The growth of *P. pangasius* was poor as it attained average increment of 196.6g. Total increment of fish/day and net production per hectare was 0.91 g and 1,472kg respectively.

Islam and Dewan (1986) studies 180 ponds in four districts and observed that 47.0% of fish farmers cultured indigenous carp, 2.0% exotic carp and 51.0% cultured both types. They also found that 34% farmers used both fertilizer and feed and either fertilizer or feed was supplied by 8.0% and 33.0% farmers, respectively.

Chuapoehuk, and Pothisoong, (1983) reared catfish fry (*Pangasius sutchi*) through feeding with artificial diets of different protein levels and reported that diet containing 25% protein was best for optimum growth.

Chaudhury *et al.* (1978) reported the results of a study on fish production under intensive culture in a farmer's ponds. At a high stocking density of 53 fingerlings/dec (l3,320 fingerlings/ha) and regular application of feed and fertilizers, a net highest production of 29.8 kg/dec/year (7,455 kg/ha/year) obtained. This was about seven times the production level in India at that time.

Saha *et al.* (1978) recorded an increase in fish production in freshwater ponds by using fertilizer alone. Chemical fertilizer viz; urea, super phosphate and potassium chloride were applied twice a week to ponds containing silver carp, rui, catla and common carp. They stated that the fertilizers enhanced the growth of plankton, which in turn gave better growth of fish.

2.2 Water Quality Parameters

2.2.1 Physico-chemical parameters

Ghosh (2018) experimented on the physical and chemical parameter analysis of Mondal pond at Barddhaman town of Purba Barddhaman, West Bengal in India. His study period was from March 2015 to February 2016. During his research he analyzed the oxygen, free CO_2, chloride, alkalinity and PO_4. He found air temperature of air varried from 19°C to 34°C and temperature of water was 31.8°C. pH ranged from 8.2 in September to 9.5 in August. The lowest DO was 4.1mg/l observed in April and the highest was 13.1mg/l observed in December. Free carbon di-oxide varied from 2.4 mg/l to 10.2 mg/l. Chloride from 70mg/l to 165mg/l. Alkalinity level ranges from 82mg/l to 165.5mg/l and phosphate level was between 0.40 mg/l and 0.86mg/l.

Abedin *et al.* (2017) said that water quality parameters have wider verse effect on semi-intensive and intensive pond aquaculture system. He studied on water quality parameters of *Pangasius* sp. ponds under existing farming practices at the Trishal upazila in Mymensingh, Bangladesh.

Real *et al.* (2017) studied on pH, BOD, DO and water temperature and some chemical parameters like ion concentration viz. phosphate, sulphate and nitrate in the Dhaleshwari river at April 2015 to June 2015. Water temperature ranged from 29.5˚C (June) to 31.7˚C (May) and the highest mean was 31.17 ± 0.47^{o} C (May). The pH of water was in nature and ranged between 7.25 in June to 8.45 in April which was light alkaline. Average BOD was 0.87±0.19, 1.12±0.6 and 0.97±0.67 in April, May and June respectively. The highest phosphate concentration was 4.4 mg/l in May and the lowest was 1.74 mg/l in June. Nitrate was ranged from 0.51 mg/l (June) to 3.66 mg/l (April).

Haider *et al.* (2017) conducted a research on water quality indicators highlighting the availability of benthos community in ponds for 90 days at Dinajpur, Bangladesh. The study was done on 3 treatment viz. T_1 (small sized), T_2 (medium sized) and T_3 (large sized) with three replications. Various parameters were tested at fortnightly. Water temperature were 24 to 34 °C, transparency 27 to 36 cm, dissolved oxygen 3.75 to 4.97 mg/l, pH 6.16 to 7.10, total alkalinity 28 to 122 mg/l, chlorophyll-a 4.76 to 460.77 µg/l, ammonia nitrogen 0.01 to 0.70 mg/l, phosphate-phosphorus 0.12 to 0.99

mg/l, nitrite-nitrogen 0.20 to 0.26 mg/land nitrate-nitrogen 0.01 to 0.45 mg/l were found among three treatments.

Sajitha and Vijayamma (2016) monitored the pond water parameters in Kerala, India. Pond temperature varied from 26.8 to 29.6°C, pH ranged between 4.62 to 7.21 and dissolved oxygen was from 1.76 – 8.4 mg/l.

Rumpa *et al.* (2016) monitored the variation of water temperature (26 to 34℃), transparency (28 to 41 cm), DO (2.45 to 5.5 mg/l), pH (7.0 to 8.5), total alkalinity (130 to 182 mg/l) and ammonia nitrogen (0.12 to 0.3 mg/l) were within the suitable range that good for fish production.

Hossain *et al.* (2014) in his study found the average data of some water quality parameters like temperature 16.78±2.17^{0}C, transparency 32.67±1.9 cm, dissolved oxygen 5.88±2.18 mg/l, pH 8.24±0.49, total alkalinity 184.72±22.72 and ammonia nitrogen 0.21±0.05.

Munni *et al.* (2013) studied on assessment of pond water quality in some ponds at Santosh of Tangail. The parameters were temperature, pH, DO, BOD, transparency, TDS, EC, acidity, alkalinity and hardness. He found the temperature 29-38.3°C, pH 6.8- 7.12, DO 1.1-6.9 mg/l, BOD 1.4-4.2 mg/l, transparency 32.5-57.5 cm, TDS 85-164 mg/l, EC 138-274 µs/cm, acidity 20-36.3 mg/l, total alkalinity 43.5-62.5 mg/l and hardness 20-27 mg/l.

Simpi *et al*. (2011) monitored water quality parameters under their study at Hosahalli Tank in Shimoga District, Karnataka, India. Variations of physical and chemical parameters like dissolved solids, pH, DO, free carbon-dioxide and total hardness, chlorides, alkalinity, phosphate and nitrates were analyzed in every month.

Uddin, M. A. (2002) observed that temperature varied from 25.6 to 33.0°C, transparency from 11.0 to 63.5 cm, DO from 2.2 to 8.8 mg/l, pH from 6.1 to 8.88, NO_3-N from 0.01 to 0.88 mg/l, PO_4-P from 0.03 to 4.46 mg/l, total alkalinity from 45 to 180 mg/l and chlorophyll-a was from 13.05 to 1,374 µg/l.

Ahmed *et al.* (2000) analyzed the water quality parameters in carp nursery ponds at Mymensingh, Bangladesh. Average data of temperature, transparency, dissolved oxygen, pH, chlorophyll-a, total alkalinity, nitrate nitrogen, ammonia nitrogen and phosphate phosphorous were 30.58℃, 51.83 cm, 5.7 mg/l, 6.88, 5.27 mg/l, 26 mg/l, 1.12 mg/l, 0.02 mg/l and 0.78 mg/l respectively during study period.

Rahman (2000) studied the quality of water considering some elements of freshwater pond and reported that temperature varied from 21.1 to 32.2°C, transparency 12 to 41 cm, dissolved oxygen 2.39 to 10.36 mg/l, pH from 6.0 to 9.1, nitrate-nitrogen (NO_3-N) from 0.7 to 4.8 mg/l, phosphate-phosphorus (PO_4-P) 0.18 to 2.73 mg/l, total ammonia 0.03 to 2.72 mg/l and chlorophyll -a 17.80 to 457.58 µg/l.

Sarker (2000) studied the water quality parameters in relation to periphyton production in monoculture of GIFT Tilapia in Bangladesh Agricultural University fish ponds. He found water temperature to vary from 19.8 to 22.8°C, transparency from 27 to 35 cm, pH 6.8 to 8.3, dissolved oxygen 3.57 mg/l to 8.84, phosphate-phosphorus (PO_4-P) 0.49 to 4.07 mg/l and nitrate-nitrogen (NO_3-N) from 1.69 to 2.6 mg/l during his study period.

Nur (1999) studied the variation of water quality parameters in some experimental ponds situated at the Field Laboratory Complex of Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh. During the period of investigation, he found the average temperature varied from 28.60 to 31.60°C, transparency 34.10 to 93.0 cm, dissolved oxygen 3.5 to 7.5 mg/l and pH 6.6 to 8.0 mg/l.

Begum (1998) recorded temperature ranging from 25.1 to 30.1°C pH from 7.05 to 8.02 and DO from 5.06 to 7.09 mg/L in fish ponds of BAU Campus, Mymensingh during August to October, 1997.

Paul (1998) observed the water quality parameters in experimental ponds of the Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh. She recorded the various water quality parameters and found water temperature (°C) 26.7 to 33.7, pH 6.51 to 9.45, dissolved oxygen (mg/l) 0.854 to 7.85, phosphate- phosphorus (mg/l) 0.03 to 2.75, nitrate-nitrogen (mg/l) 1.1 to 6.6, total hardness (mg/l) 31 to 86, ammonia nitrogen (mg/l) 0.01 to 0.99 and chlorophyll g (µg/l) 11.9 to 154.7.

Nirod (1997) examined some physical and chemical parameters of water in 9 ponds of mola fish (*Amblypharyngodon mola*) at BAU, Mymensingh. He found the ranges of temperature 21.80 to 31.10°C, transparency 25 to 67 cm, pH 6.5 to 8.5, DO 3.40 to 7.79 mg/l, total hardness 79 to 220 mg/l, total ammonia 0.10 to 0.49 mg/l, phosphate-phosphorus (PO_4-P) 0.36 to 0.67 mg/l, nitrate- nitrogen (NO_3-N) 0.20 to 1.82 mg/l and chlorophylla 1.009 to 197.54 µg/l.

Azim *et al.* (1995) calculated the mean values of temperature 26.0°C, transparency 36.2 cm, pH 7.1, total hardness 50.5 mg/L from his experiment which was conducted on a set of ponds.

Dewan *et al.* (1991) studied in Bangladesh Agricultural University pond and found water temperature 30.2 ºC to 34.0 ºC, pH from 6.6 to 8.8, sechi disc range from 54-90cm, DO 2.2-8.8 mg/L and ammonia-nitrogen 0.5-6.2mg/L.

According to Boyd (1982) total alkalinity must be more than 20ppm where fertilizer was used. Fish production increases with the increase of total alkalinity in fertilized ponds. Toxicity of ammonia decrease with increasing carbon dioxide concentration. The toxicity of unionized ammonia depends on pH, when the pH is high, unionized ammonia is toxic at a lower concentration.

Bhuiyan (1970) stated that, the low value of pH (below 7) not suitable for aquaculture. Ponds with total alkalinity 40ppm or more are considered as more productive than others.

Swingle (1967) stated that good relationships between pH and fish growth and got the pleased results and pH 6.5 to 9.0. He also observed that water pH more than 9.5 was not productive and pH more than 10.0 was lethal for fish.

2.2.2 Biological parameters

Ansari *et al.* (2015) studied on phytoplankton population and water quality observation of ONGC Pond at Hazira. Total 73 genera of phytoplankton under 4 classes viz., Euglenophyceae, Chlorphyceae, Bacillariophyceae and Cyanophyceae were identified. Others classes were dominated by Chlorophyceae.

Asha *et al,* (2015) conducted a study on results of water quality on plankton abundance in selected ponds of Nedumangad Block Panchayat, Kerala, India. They researched on plankton diversity of 36 selected ponds. From the plankton study result it was found that phytoplankton of the class cyanophyceae, chlorophyceae, bacillariophyceae and zooplanktons were zoea larvae and mysis larvae of prawn.

Verma *et al*. (2013) studied on monthly fluctuations of zooplankton in freshwater ponds of Damoh district, India. Their research carried for 12 months from June 2011to May 2012. The zooplanktons were under five groups viz. Rotifera, Crustacean, Cladocera, Protozoa and Copepoda. 31.48% Rotifera, 18.52% Cladocera 9.26% Copepoda, 25.92% Crustaceans and 14.82% Protozoa were found. 54 genera were identified during the study period.

Ekhala *et al.* (2013) carried out Phytoplankton study and also water quality on village pond. Total 46 species of phytoplankton were identified under the class of Euglenophycae, Chlorophyceae, Bacillariophyceae and Cyanophyceae. Maximum genera were under Chlorophyceae, second and third were Bacillariophyceae and Euglenophycae.

Gonçalves *et al.* (2011) studied on plankton community and photosynthesis situation in a eutrophic lake of Patagonia, Argentina. They also studied the grazer abundance and UVR. Crustaceans showed the alternating dominance between cladocerans (*Daphnia spinulata*) and copepods (*Metacyclops mendocinus*).

Uddin (2002) gave an account of phytoplankton in six experimental ponds of the Field Laboratory of the Faculty of Fisheries, BAU, Maymenshing. 35 genera of phytoplankton belonging to Bacillariophyceae (6), Chlorophyceae (18), Cyanophyceae (8) and Euglenophyceae (3) were recorded. Chlorophyceae was found to be the most dominant group and Bacillariophyceae was the least abundant group among phytoplankton during the study period.

Raihan (2001) studied the plankton abundance in polyculture of carps with small fish puti and mola for the period of five months in the Field Laboratory of BAU, Mymenshing. He identified 31 genera of phytoplankton belonging to Bacillariophyceae (4), Chlorophyceae (18), Cyanophyceae (6) and Euglenophyceae (3). Among phytoplankton Chlorophyceae was the dominent group and Euglenophycea was the least abundant group.

Hoque (2000) carried out an experiment on the effects of periphyton on monoculture of *Puntius gonionotus* in Bangladesh Agricultural University campus, Mymensingh. During the study period he identified 33 genera of phytoplankton belonging to 5 different groups of Bacillariophyceae, Cyanophyceae, Euglenophyceae, and

Dinophyceae and 13 genera of zooplankton belonging to 4 groups of Cladocera, Copepoda, Rotifera and nauplius.

Nur (1999) experimented the growth and production performance of Catla (*Catla catla*) and mirror carp (*Cyprinus carpio*) of different stocks in six ponds at the Field Laboratory Complex, Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh. During his research he identified 33 genera of phytoplankton including Bacillariophyceae (5 genera), Chlorophyceae (19 genera), Cyanophyceae (6 genera) and Euglenphyceae (3 genera) and 11 genera of zooplankton including Crustacea (4 genera) and Rotifera (7 genera).

Nirod (1997) studied the growth and production of mola (*Amblypharyngodon mola*) under different stocking densities and studied on the plankton abundance in the pond water. During the investigation, he found that phytoplankton population was comprised of four groups; Bacillariophyceae (3 genera), Chlorophyceae (15 genera), Euglengphygeae (2 genera) and Cyanophyceae (5 genera), and two groups of zooplankton belonged to Crustacea (5 genera), and Rotifera (7 genera).

Wahab *et al.* (1995) found five major groups of phytoplankton. These are Bacillariophyceae (7 genera), Chlorophyceae (22 genera), Cyanophuyceae (9 gemera), Euglenophyceae (3 genera), and Rhodophyceae (l genera), On the other hand, zooplankton was comprised of only Crustacea and Rotifera.

Dewan *et al.* (1991) identified 24 genera of phytoplankton belonging to Chlorophyceae (15 genera), Bacillariophyceae (3 genera), Euglenophyceae (2 genera), Rhodophyceae (1genera) and Cyanophyceae (3 genera), and 9 genera of zooplankton belonging to Hydrozoa (1 genera), Rotifer (3 genera) and Crustacea (5 genera) in some reared ponds in Bangladesh

Banu *et al.* (1987) worked on some aspects of reproductive cycle and history of eggs of *Anabas testudineus* (Bloch) where they found a wide variation in abundance of plankton ranging from 4,093 to 3,52,809 cells/L of water. They identified 27 different genera among which the dominant genera were *Anabaena, Anabaenopsis, Microcystis, Chlorococcus, Pediastrum, Melosiru, Brachiunus, Keratella, Filinia, Daphnia, Diaphanosoma* and *Cyclops*.

Chapter - 3

METHODOLOGY

Methodology is the analysis of principles and systematic study on the objectives of a research. It helps to achieve the goals of the research. Success of a research work is mostly depends on selection of proper methodology. Data collection method depends on the objectives of the research.

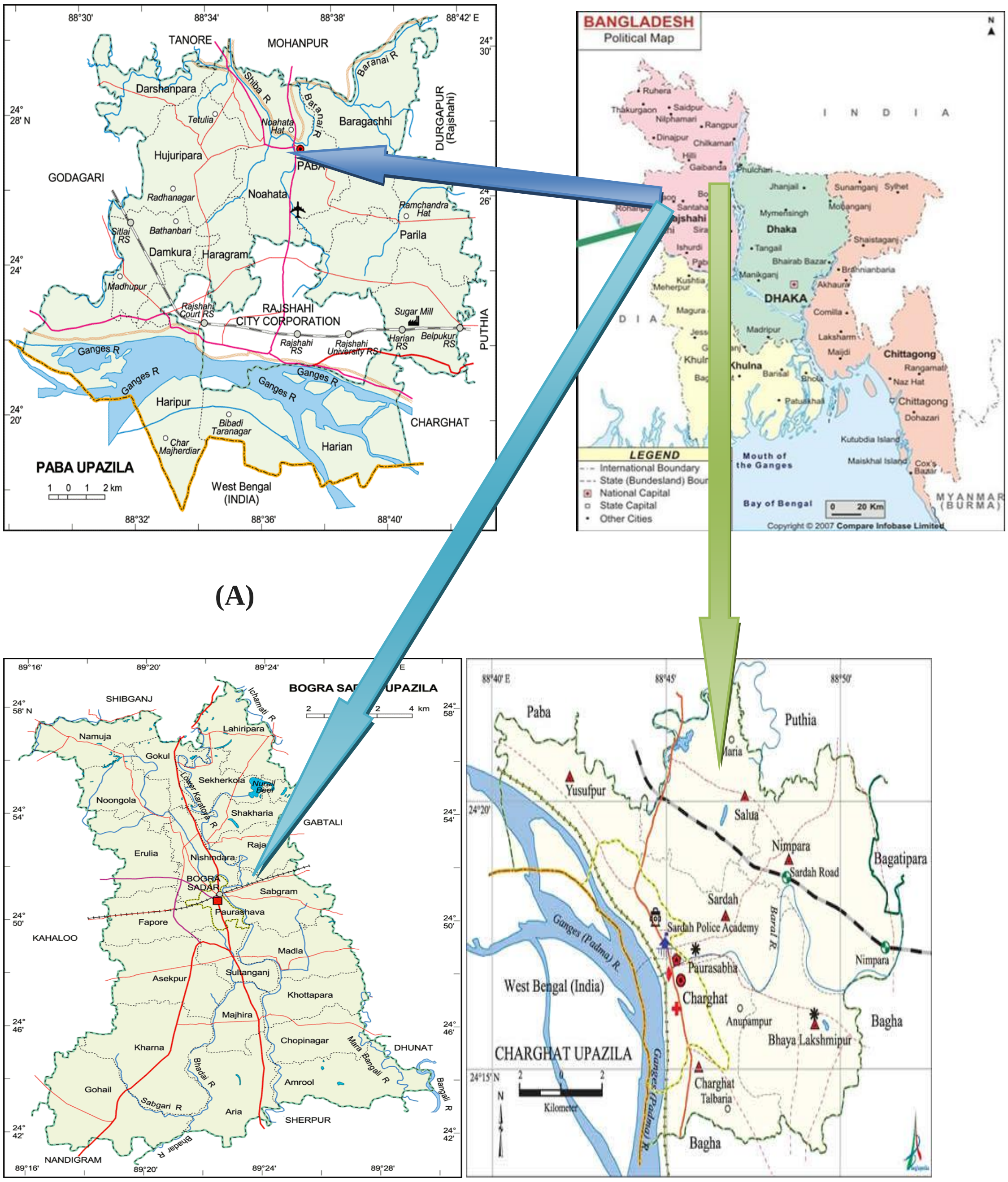
3.1 Study Area

The research sites were considered in North-West region of Bangladesh namely, at Paba upazila (Rajshahi University Area), Charghat upazila under the district of Rajshahi and Bogura sadar upazila of Bogura District.

Area of Paba Upazila is 280.42 sq km. It is surrounded by Mohanpur and Tanore upazilas of Rajshahi and West Bengal state of India is on the North,

Charghat upazila is surrounded by Puthia, Durgapur and Godagari upazillas. Puthia is on the South, Durgapur is on the East and on the West it was Godagari upazila. In the North of Charghat it is the Padma River. It is consists of 164.52 sq km.

Bogra Sadar Upazila's area is 197.75 sq km. It is an old and very well-known district of Northern Bangladesh. It is bounded by Shibganj (Bogra) upazila, Shahjahanpur upazila, Gabtali upazila and Kahaloo upazila on the North, South, East and West respectively.



(A)

(B) **(C)**

Figure 3.1: Study area: (A) Paba upazilla, (B) Charghat upazila under Rajshahi district and (C) Bogra sadar upazila under Bogra district

3.2 Study Period

This study was done from August 2015 to March 2019. During study period observed the water depth fluctuation with the season, water quality study for suitable environment of fish species, monthly sampling to observe the growth performance and data input on the Excel Sheet and analyzed.

3.3 Experiment methodology

To increase water retention capacity three different water retention techniques of (i) digging and polythene lining with clay soil, (ii) digging and compost layering and (iii) only digging were build up. A total of 27 seasonal ponds in three locations (9 at Rajshahi University campus, 9 at Charghat-Bhagha and 9 at Bogra Sadar) were selected from baseline survey data of 180 ponds in the selected loctions. The selected seasonal ponds were dug to 10 feet with the dredging machine. Water level was maintained 8 feet for T_1, 7 feet for T_2 and 6 feet for T_3.

3.4 Experimental Design

To conduct the research, a total of 27 seasonal ponds were selected and each sites contains 9 ponds with three treatments and each treatment had three replications. Under Paba upazila 9 model ponds were selected at the university of Rajshahi instead of Paba Upazila, 9 for Charghat and 9 for Bogura Sadar Upazila. In addition, five (5) seasonal controlled ponds were selected as one treatment under five replications in the study area for evaluating the water depth and production with the model ponds.

Three experimental designs were selected for this study. Three study areas were selected for these three experiments. The study areas were Rajshahi University area, Charghat upazila and Bogra sadar upazilla.

3.4.1 Rajshahi University Area: For research work the nine ponds were selected from the University of Rajshahi. After site selection, length and width of each pond were measured carefully with the measuring tape.

All nine ponds were excavated/constructed using a dredging machine for achieving the depth of 10 feet. After digging the ponds polyethyne sheets were placed on the bottom layer then six inches of clay soil and organic fertilizer was applied on the polythene layer (Figure 2). And then use of liming, organic and inorganic fertilizers was used for increasing the natural food for fish. The water level was maintained as the time of stocking like previous year at 8 feet, 7 feet and 6 feet for T_1 (pond no-6, 7 and 9), T_2 (pond no-1, 4 and 8) and T_3 (pond no-2, 3 and 5), respectively.

Then the slope, embankment and bottom of the model ponds soils installed firmly used by the bamboos. When model ponds were ready then lime was used at the rate of 1 kg/decimal then the following items like cowdung at the rate of 5 kg/decimal, inorganic fertilizer i.e., urea and T.S.P was applied at the rate of 150 g/decimal and 100 g/decimal, respectively. The organic fertilizer was applied for increases the primary productivity and the chronologically water level was increased to the model ponds.

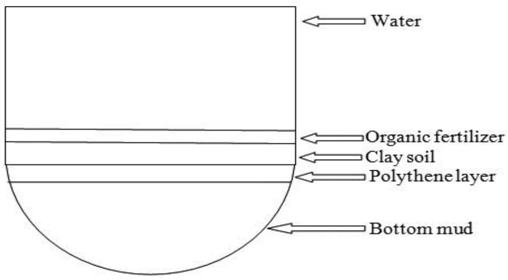


Figure 3.2: Model pond diagram in the Rajshahi University

Plate 3.1: Pond Condition before re-excavation in the study area

Plate 3.2: Pond re-excavation according to the experiment in the study area

Plate 3.3: Pond Condition after re-excavation in the study area

3.4.2 Charghat Upazilla: 9 ponds were selected in Charghat upazila. After site selection, length and width of each pond were measured carefully with the measuring tape.

Ponds were dug for achieving the depth of 11 feet, 10 feet and 9 feet for T_1 (pond no-3, 4 and 9), T_2 (pond no-5, 6 and 7) and T_3 (pond no-1, 2 and 8) respectively. After digging the ponds, one feet clay soil was applied on the bottom of the ponds to increase the water holding capacity and thus the final depth of the ponds were 10 feet, 9 feet and 8 feet for T_1, T_2 and T_3 respectively. Then the slope, embankment and bottom of the model ponds soils installed firmly used by the bamboos. When model ponds were ready then lime was used at the rate of 1 kg/decimal then the following items like cow dung at the rate of 5 kg/decimal, inorganic fertilizer i.e., urea and T.S.P was applied at the rate of 150 g/decimal and 100 g/decimal, respectively.

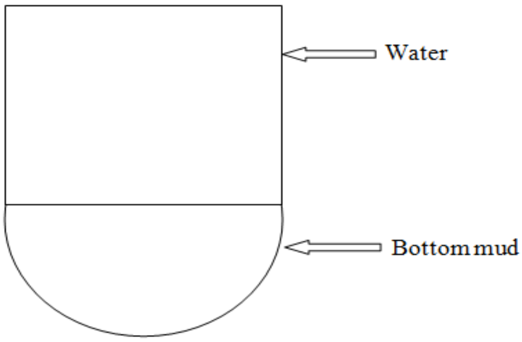


Figure 3.3: Model pond diagram in the Charghat upazila

Plate 3.4: Pond condition before re-excavation of the study area

Plate 3.5: Pond excavation in the study area

Plate 3.6: Pond condition after re-excavation in the study area

3.4.3 Bogra Sadar Upazilla: 9 ponds were selected from the Bogra Sadar Upazila, Bogra. After site selection ponds were measured with the measuring tape. Ponds length and width were measured carefully. Ponds were dug with the dredging machine. After digging the ponds one feet compost layer was set up to increase the water holding capacity of model ponds on the bottom layer. Then the slope, embankment and bottom of the model ponds soils installed firmly used by the bamboos. When model ponds were ready then lime was used at the rate of 1 kg/decimal then the following items like cow dung at the rate of 5 kg/decimal, inorganic fertilizer i.e., urea and T.S.P was applied at the rate of 150 g/decimal and 100 g/decimal, respectively. The compost was applied one feet for increases the primary productivity and the chronologically water level was increased to the model ponds. Then the water level was maintained at 8 feet, 7 feet and 6 feet for T_1(Pond No. 6,7,9), T_2 (Pond No. 1,4,8)and T_3 (2,3,5) respectively.

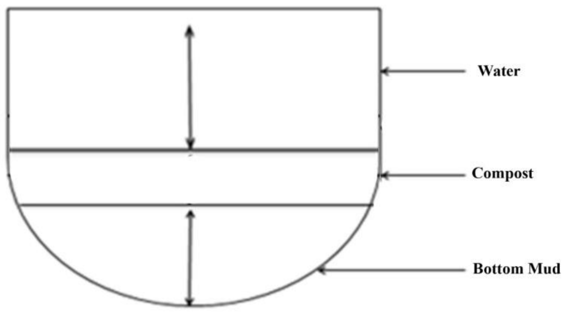


Figure 3.4: Model pond diagram in the Bogra Sadar upazila

Plate 3.7: Pond condition before re-excavation in the study area

Plate 3.8: Pond excavation in the study area

Plate 3.9: Pond condition after re-excavation

3.5 Stocking Density

After pond preparation fishes were stocked in a certain stocking density. For the first experimental period a total of 80 fish fry were stocked per decimal of each of three research sites. Four types of fish species were stocked, namely *Hypophthalmichthys molitrix, Labeo rohita*, *Cirrhinus cirrhosus*, *Barbonemus gonionotus* and *Oreochromis niloticus.* Fish species and stocking density is given below in the table 3.1.

Table 3.1: Stocking density (fry/decimal) of cultured fingerlings in each fields

Treatment	**Water depth feet**	**Replication**	**Stocking density/ Decimal**									
			H. molitrix		***Labeo rohita***		***Cirrhinus cirrhosus***		***Barbonemus gonionotus***		***Oreochromis niloticus***	
			1st Year	**2nd Year**	**1st Year**	**2nd Year**	**1st Year**	**2nd Year**	**1st Year**	**2nd Year**	**1st Year**	**2nd Year**
T_1	8	R_1	20	15	25	20	25	20	5	3	5	3
		R_2	20	15	25	20	25	20	5	3	5	3
		R_3	20	15	25	20	25	20	5	3	5	3
T_2	7	R_1	20	15	25	20	25	20	5	3	5	3
		R_2	20	15	25	20	25	20	5	3	5	3
		R_3	20	15	25	20	25	20	5	3	5	3
T_3	6	R_1	20	15	25	20	25	20	5	3	5	3
		R_2	20	15	25	20	25	20	5	3	5	3
		R_3	20	15	25	20	25	20	5	3	5	3

3.5.1 Sampling procedure

Fish sampling of the experimental ponds was done randomly at an interval of 30 days by using seine net and cast net in order to check the growth performance and set the feeding rate. Growth of fish in each sampling was taken by weight of fish by using an electric balance.

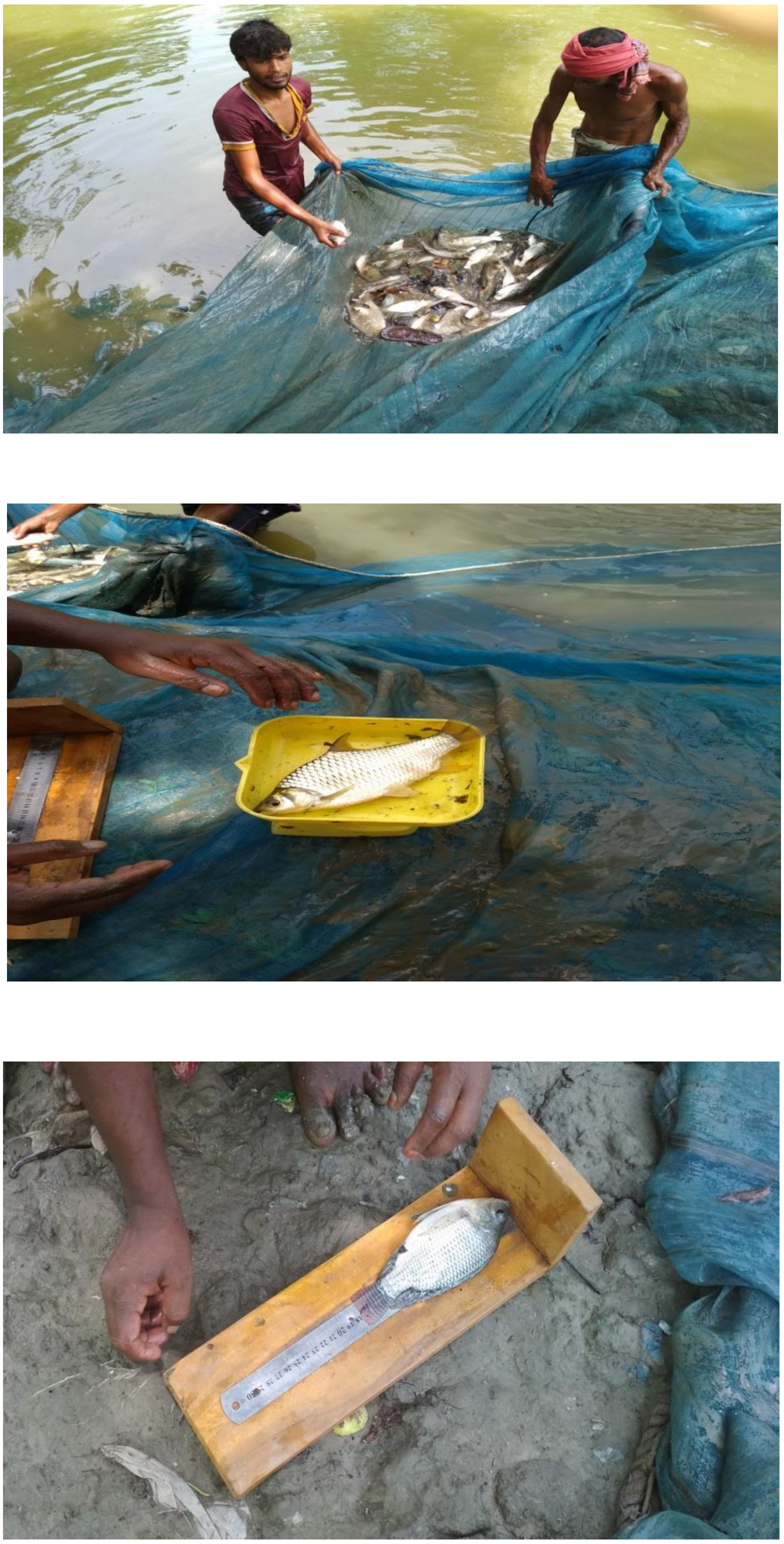


Plate 3.10: Sampling procedure of the study areas

3.5.2 Estimation of growth performance

After final harvesting, final weight was taken and recorded. After that the following parameters were used to evaluate the growth and production of the fishes.

(a) Mean weight gain (g) = Mean final weight (g) – mean initial weight (g)

(b) Specific growth rate (SGR, % bwd^{-1})

Specific growth rate (SGR, % bwd^{-1}) was calculated as-

[In (final weight) – (initial weight)] / culture period (day) × 100

(c) Survival rate: After completion of the experiment at 245 days the number of total live fries in ponds was counted separately for calculation of survival rate.

$$\text{Survival rate (\%)} = \frac{\text{Number of fish at harvest}}{\text{Total number of fish stocked}} \times 100$$

(d) Feed Conversion Ratio (FCR)

The Feed Conversion Ratio (FCR) is the amount of food required to produce a unit of fish. It was expressed as-

$$\text{FCR} = \frac{\text{Total amount of food given (kg)}}{\text{Total amount of fish produced (kg)}}$$

A

B

C

Plate 3.11: Fry releasing activity in the study area (A: Rajshahi University area, B: Charghat Upazilla, C: Bogra Sadar area)

3.6 Feedings & Management

After stocking, fertilization had done twice daily in all the ponds (cow dung 50 kg/ha, urea 1.25 kg/ha and TSP 1.25 kg/ha). Only supplementary feed had been used at the rate of 4% of fish body weight with the help of feeding trays. Marketable fish feed had been used as supplementary feed (Bangla Feed Mill Ltd.) and this feed prepared by bangle fish feed industry had been given especially for the fishes with the protein content of minimum 25%. Fish's health has been checked every month by netting. Feed composition (%) is presented in table 3.2.

Table 3.2: Feed composition (%) of the supplementary feed (Bangla feed)

Code No.	Crude Protein (Lowest)	Fat (Lowest)	Carbohydrate (Highest)	Moisture (Highest)	Fiber (Highest)	Ash (Highest)	Calcium (Highest)	Phosphorus (Lowest)
503	25	5	38	12	8	20	1.9	0.5

3.7 Water depth monitoring

To monitor the water depth regularly of the ponds, a PVC pipe was setup in the middle of the each pond with marking in inches and noted down.

Figure 3.5: Water depth monitoring pipe

3.8 Data collection

Secondary data was collected from the meteorological department to estimate the co-relation of water depth with rainfall and water depth with evaporation. To know the soil texture of the study ponds, soil was tested from the soil research & development institute, Rajshahi.

3.9 Controlled ponds

The five (5) seasonal controlled ponds were selected in the study area for evaluating the water depth and production with the model ponds. The production data and water depth data were estimated by direct observation method. The observation was done from January 2017 to December 2018.

3.10 Study of water quality parameters

Water quality parameters were monitored two times at a month over the study period. Water temperature (°C), transparency (cm), and pH, were measured beside the pond. Dissolved oxygen (mg/l), nitrate-nitrogen (mg/l), phosphate-phosphorus (mg/l), total ammonia (mg/l), and total alkalinity were measured at Fisheries Department, University of Rajshahi.

3.10.1 Study of the physical parameters: The following physical factors were determined from the limnological aspects-

Temperature: Temperature of water of pond was recorded in the field with the help of a Celsius thermometer.

Transparency: Transparency of water was measured by a Secchi disc of 40 cm in diameter.

3.10.2 Study of the chemical parameters: The following chemical factors were determined.

pH: Hydrogen ion concentrations (pH) of water samples were determined at the pond site by using pH paper.

Dissolved Oxygen (DO): For determining dissolved oxygen (DO) of water, samples were collected from the ponds and measured by a HACH Kit, (Model DR 2010, USA).

Nitrate-nitrogen: Nitrate-nitrogen from the water samples was determined by using a HACH Kit (DR-2010, USA) and necessary reagent pillow Nitro Ver-5.

Phosphate-phosphorus: Phosphate-phosphorus of the pond water samples was determined by using a HACH Kit (DR-2010, USA) and necessary reagent pillow PhosVer-5.

Total Ammonia: Total ammonia was determined from collected water samples with the help of a direct reading spectrophotometer, HACH Kit, (Model DR 2010, USA). The chemical reagent Rochelle salt and Nasslar reagents were used as chemical reagents for total ammonia measurement.

Total alkalinity: Total alkalinity of the pond water samples was measured titrimetrically by using 0.02 N sulfuric acid and methyl orange as indicator according to the standard procedure and method (APHA, 1992)

3.10.3 Study of biological parameters

For the study of plankton both phyto and zooplankton of water was studied. For the analysis water samples of five litres was collected randomly from five locations in each pond at mid-depth and surface and passed through a plankton net (mesh size 45pm) and finally concentrated to 50 ml. Then concentrated samples were poured into small, sealed plastic bottles and preserved in 10% formalin and then studied subsequently.

Identification of plankton: Identification of plankton (phytoplankton and zooplankton) up to generic level was carried out.

Plate 3.12: Water Quality parameters measurement in the study areas

3.11 Data processing and analysis

After data collection raw data were checked and revised carefully before the final entry. Those data were noted` as local units were converted into international units. After processing data were transferred to a excel sheet systematically and carefully from which tables were prepared for reveal of the findings of the research. After completing entry of the data, they were tabulated into a preliminary data sheet of a computer and compared with computer spread sheets to ensure the accuracy of the data entered. Then the data were analyzed with computer programs, Microsoft Excel and SPSS (Statistical Package for Social Science).All statistical analysis was performed on SPSS Statistics-20 software package and one-way ANOVA tests were used to compare returns per unit area from different management practices.

3.12 Result Preparation

Final results will be calculated by comparing net production of three study areas with control ponds and pond depth. Here three study areas will be considered as three treatments and control pond will be treatment four. All the results would be compared with controlled ponds.

Chapter - 4

RESULTS

During the first experiment in 2017, water depth was found above 3 feet in five seasonal controlled ponds for 6 months in Paba (RU campus) upazila, 3 feet on an average period of 5 months at Charghat Upazilla and Bogura sadar Upazilla. Whereas model ponds lengthened round the year and the highest average water depths were 6.43 feet in T_1 at Paba upazilla, 5.47 feet in T_1 for 6 to 8 months at Charghat upazilla and in Bogura sadar Upazila 7.00 feet at T_1 for the year round. In this experiment the mean water quality parameters were within the suitable range where there was no significant (p>0.05) difference in temperature, transparency, pH, DO and CO2 among the treatments. The harvesting period was in December. The highest specific growth rate (SGR) 1.33% was found in Paba and Charghat. The highest food conversion ratio (FCR) 0.66 was in Bogura. In Paba upazilla net production was 16.04, 17.2 and 15.01 Kg/d for T_1, T_2 and T_3 respectively whereas average 4.35 kg/decimal was in the controlled pond which was 268.74%, 295.40% and 245.06% increased for T_1, T_2 and T_3 respectively . In Charghat the net production was 14.79, 18.6 and 18.44 Kg/ d for T_1, T_2 and T_3 respectively whereas 4.32 kg/d for control pond which was 112.74%, 178.86% and 176.46% higher. At Bogura sadar upazila the net production was 12.85, 12.72 and 12.7 Kg/ d for T_1, T_2 and T_3 respectively and for control pond it was 5.14 kg/d which was 186.23%, 183.09% and 182.61% higher. During second experiment in 2018, the highest mean water depth in model ponds were found in Paba and Charghat (5 feet) where control pond have 2 feet. In Bogura Sadar upazila the highest water depth was found 4.29±0.63 feet for round the year in the model ponds whereas 2.39 feet for the controlled pond. During study time it was found that the mean water quality parameters were within the suitable range where there was no significant (p>0.05) difference in temperature, transparency, pH, DO and CO2 among the treatments. The initial weight of fish fry was 3.08±0.004, 3.09±0.01 and 3.10±0.01 for Paba, Charghat and Bogura Sadar respectively. The Specific Growth Rate (SGR) was found highest in Paba (2.35%) and Food conversion ratio (FCR) was also highest (1.47) in Paba. Average fish production of five control ponds was found highest in Bogura 5.28 kg/decimal in the study period whereas at the same time the bottom layered polythene based model ponds at Rajshahi university area production yielded 253.02 higher against the control ponds. The average net production was more than 3 times better in model ponds than the controlled ponds. Maximum net production was found in polythene based model ponds at Paba upazila due to increase water holding capacity of ponds and scientific fish culture techniques.

4.1 Improving water retention capacity of three ponds

4.1.1 Soil Condition: Before pond preparation soil type of Rajshahi University area was clay loam, sand percentage was highest in T_1 (40.00%), silt (34.67%) and clay (30.33%) was highest in T_3. But after pond preparation the soil became clay. Silt percentage decreased from 40 to 24 and clay percentage was increased from 28.67 to 48.00. Particle size distribution and soil type of Rajshahi University area are presented in table 4.1.

Table 4.1: Soil condition before and after pond preparation of Rajshahi University area

Treatments	Sand (%)		Silt (%)		Clay (%)		Texture classes	
	Before	After	Before	After	Before	After	Before	After
T_1	40.00	25.00	31.33	27.00	28.67	48.00	Clay loam	Clay
T_2	39.00	24.00	32.00	28.67	29.00	47.33	Clay loam	Clay
T_3	35.00	26.67	34.67	27.00	30.33	46.33	Clay loam	Clay
Average	38.00	25.22	32.67	27.56	29.33	47.22	Clay loam	Clay

Five control ponds were selected for this research. In Paba upazilla the control ponds were mostly clay loamy and soil percentage were high than clay particles. Sand particles were ranged from to36.45% 42.03% whereas clay particles were from 28.00 to 31.00%.Soil condition of control ponds is presented in table 4.2.

Table 4.2: Soil texture of control ponds of Paba upazilla

Pond No.	Sand (%)	Silt (%)	Clay (%)	Texture classes
1	42.03	32.34	28.67	Clay loam
2	39.05	33.08	28.00	Clay loam
3	38.50	34.67	30.03	Clay loam
4	40.00	31.65	29.80	Clay loam
5	36.45	32.89	31.00	Clay loam
Average	39.20	32.93	29.50	Clay loam

In Charghat Upazilla the soil was also sandy before pond preparation. The highest sand particle (41.0%) was in T_1 and the lowest (27.33%) clay particle was in $T_{1.}$ Clay particle was increased 47.67% from 27.33% in T_2 by using clay soil during pond preparation. Lowest sand particle (23.33%) was in the T_1 (Table 4.3).

Table 4.3: Soil conditions before and after pond preparation of the Charghat upazila

Treatment	Sand (%)		Silt (%)		Clay (%)		Texture classes	
	Before	After	Before	After	Before	After	Before	After
T_1	39.67	23.64	31.99	30.59	28.34	45.77	Clay loam	Clay
T_2	38.50	26.31	34.08	27.69	27.42	46.00	Clay loam	Clay
T_3	35.05	25.33	34.00	29.50	30.95	45.17	Clay loam	Clay
Average	37.74	25.09	33.35	29.26	28.90	45.65	Clay loam	Clay

Selected five control ponds of Charghat pazilla were mostly clay loamy and soil percentage (39.70%) were high than clay particles (29.04%). Soil texture of control ponds of Charghat upazilla is given below in table 4.4.

Table 4.4: Soil texture of control ponds of Charghat upazilla

Pond No.	Sand (%)	Silt (%)	Clay (%)	Texture classes
1	39.70	31.44	29.04	Clay loam
2	37.50	32.08	28.12	Clay loam
3	36.57	35.57	27.75	Clay loam
4	38.00	32.99	28.80	Clay loam
5	35.54	33.08	30.00	Clay loam
Average	37.46	33.03	28.74	Clay loam

In Bogra Sadar upazilla the soil condition was sandy before pond preparation. The highest sand particle (38.67%) was in T_1 and the lowest clay particle (28.00%) was in $T_{1.}$ After pond preparation the clay particle was increased about 47.33% in T_1 and the sand percentage was decreased about (21.67%) in the T_1. Detail was presented in table 4.5.

Table 4.5: Soil conditions before and after pond preparation of the Bogra sadar upazila

Treatment	Sand (%)		Silt (%)		Clay (%)		Texture classes	
	Before	After	Before	After	Before	After	Before	After
T_1	38.67	21.67	33.00	31.00	28.33	47.33	Clay loam	Clay
T_2	38.00	25.33	34.00	28.67	28.00	46.00	Clay loam	Clay
T_3	36.00	26.33	34.00	27.00	30.00	46.67	Clay loam	Clay
Aveg	37.56	24.44	33.67	28.89	28.78	46.67	Clay loam	Clay

Selected five control ponds of Bogura Sadar Upazilla were clay loamy. Average sand was 37.36%, average silt was 33.43% and average clay was 28.86%. Details are given in table 4.6.

Table 4.6: Soil texture of control ponds of Bogura sadar upazilla

Pond No.	Sand (%)	Silt (%)	Clay (%)	Texture classes
1	37.77	32.00	28.33	Clay loam
2	38.90	33.00	29.00	Clay loam
3	36.13	34.00	31.00	Clay loam
4	35.50	33.99	28.80	Clay loam
5	38.54	34.18	27.20	Clay loam
Average	37.36	33.43	28.86	Clay loam

In comparison of soil condition of three study areas with control ponds, was found that after pond preparation sand percentage was low and clay percentage was high but in control ponds sand percentage was always high. In the three study areas after pond preparation the highest sand was 25.22% whereas in control ponds it was 38.00%.Soil texture of all control ponds were clay loamy but after pond preparation model ponds of all upazillas became clay. Details are presented in the table 4.7 below:

Table 4.7 Soil condition of ponds under three systems with control ponds

Treatment	Sand (%)		Silt (%)		Clay (%)		Texture classes	
	Before	After	Before	After	Before	After	Before	After
RU area	38.00	25.22	32.67	27.56	29.33	47.22	Clay loam	Clay
Charghat	37.74	25.09	33.35	29.26	28.90	45.65	Clay loam	Clay
Bogura	37.56	24.44	33.67	28.89	28.78	46.67	Clay loam	Clay
Control	38.00		33.13		29.03		Clay loam	

4.1.2 Pond Water Depth of 2017

After set up the experiment it was highly emphasized on water depth recording. Water depth was recorded from May 2017 to April 2018 for the first year experiment in three study areas.

4.1.2.1 Rajshahi University area (Paba Upazilla)

At Rajshahi University area maximum mean water depth was found in T_1 (7.21±0.32 feet) in the month of August due to rainy season. No significant ($p>0.05$) difference of water depth was found in the month of October and December where significant ($p<0.05$) difference of water depth was found in the rest month among treatment in the model ponds. The average water depths were 6.43 feet, 5.71 feet and 5.31 feet for T_1, T_2 and T_3, respectively (Table 4.8).

Table 4.8: Monthly variation of water depth (feet) of the model ponds in Rajshahi University area

Name of month	T1 (Mean±SD)	T2 (Mean±SD)	T3 (Mean±SD)	Average
May	5.06 ± 0.64^{b}	3.95 ± 0.21^{a}	3.48 ± 0.10^{a}	4.16
June	5.53 ± 0.38^{b}	4.55 ± 0.25^{a}	4.00 ± 0.22^{a}	4.69
July	6.50 ± 0.49^{b}	5.27 ± 0.05^{a}	4.93 ± 0.10^{a}	5.56
August	7.21 ± 0.32^{c}	6.27 ± 0.16^{b}	5.64 ± 0.02^{a}	6.37
September	6.83 ± 0.03^{c}	6.49 ± 0.04^{b}	5.90 ± 0.10^{a}	6.40
October	6.93 ± 0.01^{a}	6.54 ± 0.48^{a}	6.38 ± 0.34^{a}	6.61
November	6.56 ± 0.16^{b}	6.06 ± 0.24^{a}	5.92 ± 0.26^{a}	6.18
December	6.80 ± 0.14^{a}	6.54 ± 0.17^{a}	6.24 ± 0.44^{a}	6.52
Average	6.43	5.71	5.31	5.81

Values in the same row having different superscript letters are significantly different ($p < 0.05$)

At Rajshahi University area it was found from the five seasonal control ponds that mean annual water depths were remained only 3 to 5 months. But the polythene based model ponds were lengthened 6 to 8 months. The controlled five seasonal mean water depths of ponds were above 3 feet for 6 months that was suitable for fish culture whereas in model ponds water depths were more than three feet round the year. Monthly variation of water depth of controlled ponds of Rajshahi University area is presented in the table 4.9 below:

Table 4.9: Monthly variation of water depth (feet) of the controlled ponds at Rajshahi University Area

Month	Pond-1	Pond-2	Pond-3	Pond-4	Pond-5	Mean±SD
May	2.1	3.1	3.5	4.2	0	2.58±1.63
June	4.2	4.1	5.2	6.1	5.1	4.94±0.82
July	5.1	7.1	7.1	6.6	5.11	6.20±1.02
August	5.2	7.2	7.1	6.2	6.5	6.44±0.81
September	7.11	6.2	5.11	6.11	7.1	6.33±0.83
October	5.11	4.1	4.1	6.9	5.1	5.06±1.14
November	3.9	2.9	2.5	3.3	2.5	3.02±0.59
December	2.2	0	0	1.5	0	0.74±1.04

4.1.2.2: Charghat Upazilla

In Charghat Upazilla where digging was used, significant ($p<0.05$) difference of water depth was found in the month of June and October where no significant ($p>0.05$) difference was observed in the month of May, July, August, September, November and December among the treatments. For comparing the water depths of five controlled ponds with bottom layer digging model ponds, the monthly average water depths of seasonal ponds were above 3 feet for 5 months in a year of whereas the bottom layer digging model ponds was above 3 feet round the year. The average water depths were 4.91 feet, 4.45 feet and 4.36 feet for T_1, T_2 and T_3 respectively. Details results of water depths of model ponds of Charghat Upazilla are given below in the table 4.10:

Table 4.10: Monthly variation of water depth (feet) of the model ponds in Charghat

Name of month	T_1 (Mean±SD)	T_2 (Mean±SD)	T_3 (Mean±SD)	Average
May	3.23±0.20[a]	3.07±0.06[a]	2.66±0.66a	2.98
June	3.27±0.19[c]	2.91±0.07[b]	2.33±0.04a	2.83
July	4.59±0.21[a]	4.57±0.17[a]	4.30±0.35[a]	4.48
August	6.17±0.49[a]	6.04±0.66[a]	5.60±0.80[a]	5.93
September	6.30±0.05[a]	6.06±0.66[a]	5.82±0.01[a]	6.06
October	7.30±0.03[b]	6.50±0.28[a]	7.06±0.01[b]	6.95
November	7.07±0.83[a]	6.28±0.31[a]	7.10±1.20[a]	6.81
December	5.83±1.54[a]	4.93±0.03[a]	5.52±0.88[a]	5.42
Average	4.91	4.45	4.36	4.57

Values in the same row having different superscript letters are significantly different ($p < 0.05$)

In case of control ponds of Charghat upazila the highest mean water depth was found in the month of July and August. The lowest was found in December and May. Monthly variation of water depth of control ponds at Charghat upazilla is shown table 4.11.

Table 4.11: Monthly variation of water depth (feet) of the control ponds at Charghat Upazila

Month	Pond-1	Pond-2	Pond-3	Pond-4	Pond-5	Mean±SD
May	3	1	2	3	3	2.40±0.89
June	4	3	3	4	5	3.80±0.84
July	5	5	4	5	5	4.80±0.45
August	5	5	5	4	5	4.80±0.45
September	4	4	5	5	4	4.40±0.55
October	3	3	4	4	3	3.40±0.55
November	3	3	3	3	4	3.20±0.45
December	2	2	3	2	3	2.40±0.55

4.1.2.3 Bogura Sadar Upazilla

At compost based model ponds in Bogra Sadar upazila maximum mean water depth was found 7.70±0.23 feet, 6.62±0.12 feet and 5.37±0.32 feet for T_1, T_2 and T_3 respectively in the month of August. Significant ($p<0.05$) difference of water depth was found among the month. The average water depths were 6.44 feet, 5.50 feet and

4.58 feet for T_1, T_2 and T_3 respectively. Month wise water depth data of Bogura model ponds is presented in the Table 4.12.

Table 4.12: Monthly variation of water depth (feet) of the model ponds in Bogura

Name of month	T_1 (Mean±SD)	T_2 (Mean±SD)	T_3 (Mean±SD)	Average
May	6.40±0.10^c	5.40±0.16^b	4.40±0.11^a	5.4
June	6.80±0.11^c	5.80±0.14^b	4.74±0.14^a	5.78
July	6.76±0.17^c	5.80±0.07^b	4.81±0.02^a	5.79
August	7.70±0.23^c	6.62±0.12^b	5.37±0.32^a	6.56
September	7.26±0.04^c	6.40±0.10^b	5.20±0.10^a	6.28
October	7.10±0.20^c	6.36±0.20^b	5.10±0.15^a	6.18
November	7.00±0.10^c	6.06±0.05^b	5.00±0.10^a	6.02
December	6.96±0.15^c	5.90±0.10^b	4.72±0.05^a	5.86
Average	6.44	5.50	4.58	5.50

Values in the same row having different superscript letters are significantly different ($p < 0.05$)

For comparing the water depths of five control ponds with bottom layer compost ponds, the monthly average water depths of seasonal ponds were above 3 feet for 6 months in a year (Table 4.13).

Table 4.13: Monthly variation of water depth (feet) of the controlled ponds at Bogura sadar Upazila

Months	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5	Mean±SD
May	3	1	2	3	3	2.40±0.89
June	4	3	3	4	5	3.80±0.84
July	5	5	4	5	5	4.80±0.45
August	5	5	5	4	5	4.80±0.45
September	4	4	5	5	4	4.40±0.55
October	3	3	4	4	3	3.40±0.55
November	3	3	3	3	4	3.20±0.45
December	2	2	3	2	3	2.40±0.55
Average	**2.58**	**2.33**	**2.67**	**2.67**	**2.97**	**2.63±0.71**

4.1.2.4: Monthly Variation of water depths of three upazilla and control ponds:

In the month of May the highest water depth was found in Bogura (5.4 feet) whereas control pond's water depth was 2.46 feet. In RU area mean water depth was more than 4 feet for all the month (May to December). In Charghat upazilla the highest 6.95 feet was found in the October. In Bogura Sadar Upazilla mean water depth was more than 5 feet for all the month (May to December) and the highest was 6.56 feet at the August. In case of control ponds water depths more than two feet at May, More than three feet at the October and November. The lowest depth of control ponds was 1.84 feet at December.

Table 4.14: Monthly Variation of water depths of three upazilla and control ponds

Name of month	Rajshahi University (feet)	Control Pond (feet)	Charghat (feet)	Control Pond (feet)	Bogura (feet)	Control Pond (feet)
May	4.16	2.58	2.98	2.40	5.4	2.40
June	4.69	4.94	2.83	3.80	5.78	3.80
July	5.56	6.20	4.48	4.80	5.79	4.80
August	6.37	6.44	5.93	4.80	6.56	4.80
September	6.40	6.33	6.06	4.40	6.28	4.40
October	6.61	5.06	6.95	3.40	6.18	3.40
November	6.18	3.02	6.81	3.20	6.02	3.20
December	6.52	0.74	5.42	2.40	5.86	2.40
Average	5.81	4.41	5.18	3.65	5.98	3.65

Average water depth (feet) 0f 2017 was higher in every study area in comparison with control pond. The lowest average water depth (feet) of 2017 was also in control pond. From the figure 6 we can easily see that the increasing average water depth (feet) of all the study areas than the control pond. Figure 4.1 is presented below:

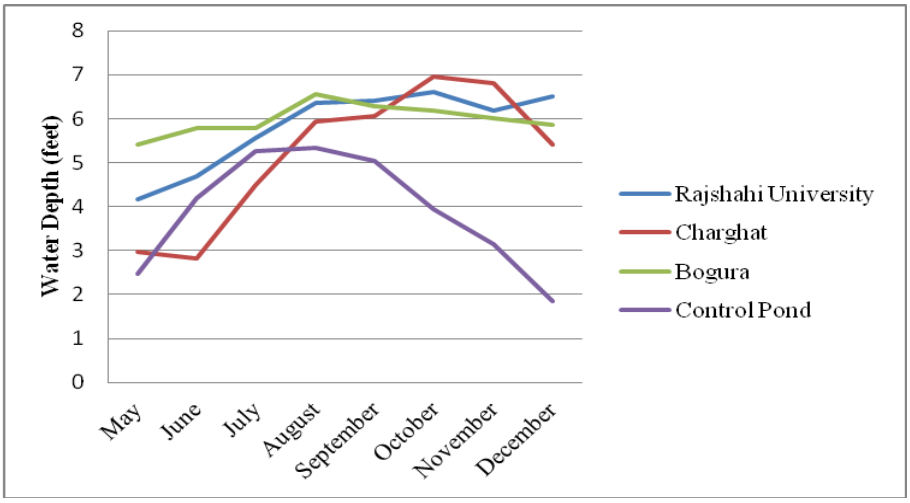


Fig: 4.1. Average water depth (feet) of model ponds and control ponds at 2017

4.1.3 Water Depth of 2018

Water depth was observed from January 2018 to December 2018 in three study areas. At all sites significant ($p<0.05$) difference of water depth was found among the three treatment in the month of April, May and there was no significant ($p>0.05$) difference of water depth in the month of January, February, March, June, July, August, September, October, November and December.

4.1.3.1 Water Depth of Rajshahi University area

In the Rajshahi university area the highest mean water depth value in T_1 was 5.81±0.51 feet in the month of January and the lowest was 4.99±0.07 in the month of July. In case of T_2 the highest mean water depth was 5.78±0.58 feet in the month of January and the lowest was 4.23±0.62 feet in the month of June. Under the T_3 the highest mean water depth was found in the month of August, it was 5.54±0.98 feet, and the lowest mean water depth was 3.93±0.56 feet in the month of in the month of May. The mean values of water depth in T_1, T_2 and T_3 were 5.43±0.25, 4.91±0.42 and 4.79±0.54 feet respectively.

Table 4.15: Monthly variation of water depth (feet) of the experimental ponds of Rajshahi University area on 2018

Name of month	T_1 (Mean±SD)	T_2 (Mean±SD)	T_3 (Mean±SD)	Average
January	$5.81±0.51^a$	$5.78±0.58^a$	$5.51±0.81^a$	5.7
February	$5.42±0.66^a$	$5.10±0.95^a$	$4.73±1.01^a$	5.08
March	$5.12±0.48^a$	$4.75±0.37^a$	$4.44±1.03^a$	4.77
April	$5.45±0.16^b$	$4.49±0.39^a$	$4.07±0.39^a$	4.67
May	$5.60±0.15^b$	$4.50±0.38^a$	$3.93±0.56^a$	4.67
June	$5.53±0.08^b$	$4.23±0.62^a$	$4.33±0.79^a$	4.69
July	$5.00±0.07^a$	$4.72±0.14^a$	$4.79±0.79^a$	4.83
August	$5.58±0.11^a$	$5.35±0.44^a$	$5.54±0.98^a$	5.49
September	$5.57±0.17^a$	$5.29±0.38^a$	$5.44±0.76^a$	5.43
October	$5.67±0.21^a$	$5.17±0.57^a$	$5.25±0.67^a$	5.36
November	$5.35±0.29^a$	$4.95±0.28^a$	$4.98±0.59^a$	5.09
December	$5.02±0.23^a$	$4.60±0.10^a$	$4.47±0.71^a$	4.69
Mean water depth	5.43±0.25	4.91±0.42	4.79±0.54	

Values in the same row having different superscript letters are significantly different ($p < 0.05$)

In the Paba Upazila average water depths of five controlled ponds were 2.675±1.94, 2.54±2.21, 2.69±2.29, 2.90±2.19 and 1.93±1.96 for ponds number 1, 2, 3, 4 and 5, respectively. In the month of January, February and March there was no water in each five ponds. April and May and December remained very low water depth. Detail results are shown in the table 4.16 below:

Table 4.16: Monthly variation of water depths (feet) of the controlled ponds at Rajshahi University on 2018

Month	Pond-1	Pond-2	Pond-3	Pond-4	Pond-5	Mean±std
January	0	0	0	0	0	0.00±0.00
February	0	0	0	0	0	0.00±0.00
March	0	0	0	0	0	0.00±0.00
April	1.5	1	1.3	1.2	0	1.00±0.59
May	2.1	3.1	3.5	3	1.3	2.60±0.89
June	4.2	4.1	5.2	4.1	2.9	4.10±0.82
July	3.7	4.5	5.3	4.8	4.1	4.48±0.62
August	5	5.4	5.1	5.2	5	5.14±0.17
September	4.9	5.2	5	4.9	4.5	4.80±0.46
October	4.5	4.4	4	5.6	3	4.70±0.62
November	3.7	2.8	2.9	4.3	2.4	3.22±0.77
December	2.5	0	0	1.8	0	0.86±1.20
Average	2.675±1.94	2.54±2.21	2.69±2.29	2.90±2.19	1.93±1.96	2.57±2.08

4.1.3.2 Water Depth of Charghat Upazila

In case of Charghat Upazila the mean values of water depth in treatments T_1, T_2 and T_3 were 4.65±1.14, 4.30±1.01 and 4.05±1.17 feet respectively. The maximum water depth 4.65±1.14 feet were recorded in treatment $T_{1,}$ whereas the minimum 4.05±1.17 feet were in T_3. The mean values of water depth in T_1, T_2 and T_3 were 4.65±1.14, 4.30±1.01 and 4.05±1.17 feet, respectively. Details of water depth variation of Charghat Upazilla is given in the table 4.17 below:

Table 4.17: Mean value (±STD) water depths (feet) of ponds in the study period 2018 at Charghat Upazila

Name of month	T_1 (Mean±SD)	T_2 (Mean±SD)	T_3 (Mean±SD)	Average
January	4.17±0.99[a]	3.60±0.13[a]	3.57±0.16[a]	3.78
February	3.28±0.59[a]	2.75±0.42[a]	2.45±0.31[a]	2.82
March	2.83 ±0.24[a]	2.23±0.26[a]	1.73 ±0.21[a]	2.26
April	4.58±0.29[b]	4.50±0.56[b]	3.80±0.32[a]	4.29
May	3.83±0.53[ab]	4.34±0.25[b]	3.40±0.17[a]	3.85
June	3.84±0.54[a]	4.29±0.12[a]	4.25±0.12[a]	4.12
July	5.05±0.29[a]	5.17±0.46[a]	4.54±0.52[a]	4.92
August	6.75 ±0.39[a]	5.9 ±0.33[a]	5.90±0.62[a]	6.18
September	6.20±0.70[a]	4.82 ±0.44[a]	5.53±1.04[a]	5.51
October	5.25±1.95[a]	4.81±0.48[a]	4.61±0.62[a]	4.89
November	5.071.80±[a]	4.70±0.45[a]	4.480.62±[a]	4.75
December	4.93±1.81[a]	4.50±0.45[a]	4.33±0.57[a]	4.58
Mean water depth	4.65±1.14	4.30±1.01	4.05±1.17	4.33

In Charghat Upazila January, February, March and April remained no water in the maximum control ponds. Average water depth of pond 1, 2, 3, 4 and 5 were 2.08, 1.95, 1.81, 2.32 and 1.95 feet respectively. Monthly variation of water depth (feet) of the controlled ponds of Charghat Upazilla is given in the table 4.18 below:

Table 4.18: Monthly variation of water depth (feet) of the controlled ponds on 2018 at Charghat upazila

Month	Pond-1	Pond-2	Pond-3	Pond-4	Pond-5	Mean±std
January	0	1	2	0	0	0.6±0.89
February	0	1	1	0	0	0.4±0.55
March	0	0	0	0	0	0±0.00
April	1	0	0	0	2	0.6±0.89
May	1.7	1.2	1.5	2.7	2.4	1.9±0.63
June	1.8	1.1	2	3	2.7	2.12±0.75
July	3.8	4	3	5	4	3.96±0.71
August	3.3	3.9	2.9	4	3.7	3.56±0.46
September	3	3.5	2.8	3.9	3	3.24±0.45
October	4.1	4.6	3.1	5.2	3.2	4.04±0.90
November	3	3.1	2.5	4.1	2.4	3.02±0.68
December	3.3	0	1	0	0	0.86±1.43
Average	2.08±1.54	1.95±1.74	1.81±1.12	2.32±2.16	1.95±1.54	2.025±0.70

4.1.3.3 Water Depth of Bogura Sadar Upazila

In the Bogura sadar Upazila mean values of water depth in treatments T_1, T_2 and T_3 were 5.21±0.59, 4.42±0.56 and 4.48±0.35 feet respectively (Table-13). The maximum water depth 6.21±0.594.65±1.14 feet were recorded in treatment $T_{1,}$ whereas the minimum 4.48±0.35 feet were in T_3. The mean values of water depth in T_1, T_2 and T_3 were 5.2±0.59, 4.42±0.56 and 4.48±0.35 feet respectively. Table 4.19 has the details results.

Table 4.19: Monthly variation of water depth (feet) of the experimental ponds 2018 at Bogura Sadar Upazila

Name of month	T_1 (Mean±SD)	T_2 (Mean±SD)	T_3 (Mean±SD)	Average
January	$4.89±0.50^a$	$4.35±0.05^b$	$4.40±0.52^a$	4.54
February	$4.21±0.48^a$	$4.02±0.05^a$	$4.14±0.40^a$	4.12
March	$4.16±0.10^a$	$3.86±0.10^a$	$4.01±0.35^a$	4.01
April	$4.88±0.56^a$	$4.02±055^a$	$4.21±0.52^a$	4.37
May	$4.85±0.65^b$	$4.30±0.60^a$	$4.10±0.39^a$	4.41
June	$4.89±0.41^b$	$3.79±0.38^a$	$4.48±0.25^a$	4.38
July	$4.36±0.15^b$	$3.57±0.42^a$	$4.01±0.30^a$	3.98
August	$6.04±0.60^c$	$5.27±0.84^b$	$5.11±0.46^a$	5.47
September	$6.26±0.35^c$	$5.23±0.35^b$	$4.98±0.48^a$	5.49
October	$5.58±0.29^a$	$4.62±0.24^a$	$4.52±0.414^a$	4.90
November	$5.28±0.44^b$	$4.63±0.18^a$	$4.50±0.46^a$	4.80
December	$5.02±0.52^a$	$4.46±0.10^a$	$4.48±0.47^a$	4.65
Average water depth	5.21±0.59	4.42±0.56	4.48±0.35	

Values in the same row having different superscript letters are significantly different ($p < 0.05$)

In the Bogura Sadar Upazila average water depths of five controlled ponds were 2.38, 2.03, 2.23, 2.36 and 2.43 for ponds number 1, 2, 3, 4 and 5 respectively. January, February, March and April maximum ponds had no water. November and December had very low water depth (less than 3 feet). Table 4.20 shows the monthly recorded data.

Table 4.20: Monthly variation of water depth (feet) of the controlled ponds at Bogura Sadar Upazila on 2018

Months	Pond 1 (feet)	Pond 2 (feet)	Pond 3 (feet)	Pond 4 (feet)	Pond 5 (feet)	Mean± Std
January	1	0	0	1	1	0.60 ±0.55
February	1	0	0	0	0	0.20 ±0.45
March	0	0	1	0	0	0.20 ±0.45
April	1	1	0	1	2	1.00 ±0.17
May	3	1	2	3	3	2.40 ±0.89
June	4	3.2	3	4	4.1	3.66±0.52
July	3.5	5	4	4.5	4	4.20 ±0.57
August	4	4.1	4.2	4	3	3.86 ±0.49
September	4	4	5	3	4	4.00 ±0.71
October	3.8	3	4	4	3.9	3.74 ±0.42
November	2	2	2.6	2.1	2.5	2.24 ±0.29
December	1.3	1	1	1.7	1.7	1.34±0.34
Average	2.38	2.03	2.23	2.36	2.43	2.29±0.16

4.1.3.4: Monthly Variation of water depths of three upazilla and control ponds at 2018:

In the month of January, February, March and April water depth ranged from 2.26 feet to 5.70 feet, whereas water depth of control ponds ranged 0.06 feet to 0.86 feet on those months of three study areas. The highest water depth was found 6.18 feet at the model pond of Charghat and in the model pond it was 4.21feet. At November and December water depth became very low 2.82 feet and 1.02 feet but in case of model ponds it was more than 4 feet at each upazilla. Monthly variation of water depth data is given below in the 4.21.

Table 4.21: Monthly Variation of water depths of three upazilla and control ponds

Name of month	Rajshahi University (feet)	Control Pond (feet)	Charghat (feet)	Control Pond (feet)	Bogura (feet)	Control Pond (feet)
January	5.70	0.00	3.78	0.6	4.54	0.60
February	5.08	0.00	2.82	0.4	4.12	0.20
March	4.77	0.00	2.26	0.0	4.01	0.20
April	4.67	1.00	4.29	0.6	4.37	1.00
May	4.67	2.60	3.85	1.9	4.41	2.40
June	4.69	4.10	4.12	2.12	4.38	3.66
July	4.83	4.48	4.92	3.96	3.98	4.20
August	5.49	5.14	6.18	3.56	5.47	3.86
September	5.43	4.80	5.51	3.24	5.49	4.00
October	5.36	4.70	4.89	4.04	4.90	3.74
November	5.09	3.22	4.75	3.02	4.80	2.24
December	4.69	0.86	4.58	0.86	4.65	1.34
Average	5.03	2.57	4.32	2.02	4.59	2.28

Average water depth (feet) of model ponds of every months was higher than control ponds in each study area. From the figure below it is easily showed that low water depth of control pond. In the year 2018 the everage water depth was found in Charghat upazila. Graphycal presentation of monthly variations of three study areas and control ponds are given below:

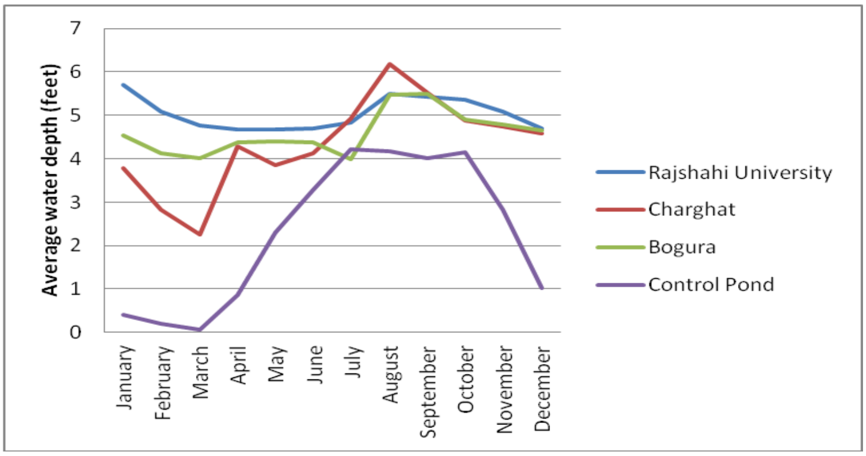


Fig 4.2: Monthly average water depth of study areas and control ponds

4.1.4 Comparison of water holding capacity between model ponds and controlled ponds in study areas

During experimental period 0f 2017 water depth was found above 3 feet in five control ponds for 6 months in Paba upazila. In paba upazila polythene based model ponds was lengthened round the year and the water depths is on an average 6.43 feet, 5.71 feet and 5.31 feet for T_1, T_2 and T_3 respectively. At the same time water depth of five seasonal control ponds in Charghat upazila was found above 3 feet on an average period of 5 months only. Whereas the digging based model ponds in Charghat upazila was lengthened for 6 to 8 months and water depth was found 5.47 feet, 5.03 feet and 5.13 feet for T_1, T_2 and $T_{3,}$ respectively. However at Bogura sadar upazila water depths of control ponds was above 3 feet on an average of 6 months. Whereas the compost based model ponds in the Bogura Sadar upazila was lengthened round the year and found 7.00 feet, 6.04 feet and 4.91 feet for $T_{1,}$ T_2 and T_3 respectively (Table-4.22).

Table 4.22: Mean water depths (feet) of model and controlled ponds in the study period at three upazilas on 2017

Location	Mean water depth (feet)			
	T_1	T_2	T_3	Controlled ponds
Paba	6.43	5.71	5.31	3.00±0.32
Charghat	5.47	5.03	5.13	3.08±0.28
Bogura	7.00	6.04	4.91	2.63±0.71

On the other hand in 2018 the average water depths of five controlled ponds of Paba upazila was recorded 2.57 which was lengthened above 3 feet only for 6 months in a year whereas by using polythene layer at the bottom of the model ponds the average water depths were recorded 5.43 feet, 4.91 feet and 4.79 feet for T_1, T_2 and T_3 respectively lengthened round the year. At the same time average water depth of five seasonal control ponds at Charghat upazila was observed above 3 feet on an average period of 5 months only. Whereas the digging based model ponds in Charghat upazila average water depths were observed 4.65 feet, 4.30 feet and 4.05 feet for T_1, T_2 and T_3 respectively and period of fish culture lengthened 11 months for T_1,10 months for T_2 and 10 monhts for T_3 which was far better than controlled ponds. However, at Bogura sadar upazila average water depths of control ponds were above 3 feet on an average only for 4 months. Whereas the compost based model ponds in the Bogura Sadar upazila was lengthened round the year and found 5.21 feet, 4.42 feet and 4.48 feet for T_1, T_2 and T_3 respectively. Results are presented in the table 4.23 below:

Table 4.23: Mean water depths (ft) of model ponds in the study period at three upazilas on 2018

Location	Mean water depth (feet)			Controlled ponds
	T_1	T_2	T_3	
Paba	5.43	4.91	4.79	2.57
Charghat	4.65	4.30	4.05	2.03
Bogura	5.21	4.42	4.48	2.29

4.2.1 Growth Performance of 2017

Initial weight, final weight, weight gain, Specific growth rate, survival rate, food conversion ratio, gross production, net production was calculated. Growth performances of 2017 of three upazilas are given below:

4.2.1.1 Rajshahi University Area

Mean final weight of different fish species varied significantly among the treatments. Mean final weight ranged between 326.43g to 502.85 g in *H. molitrix,* 221.08g to 279.48 g in *L. rohita,* 217.53g to 289.27 g in *C. cirrhosus,* 257.02g to 261.44 g in *B. gonionotus* and 439.41g and 456.56 g in *O. niloticus.* The mean final weight obtained of *H. molitrix* (502.85 g) in treatment T_1 was significantly higher than the other treatments. There was no significant ($p>0.05$) difference in mean final weight of *H. molitrix* among the treatments. The highest mean final weight of *L. rohita* was obtained 279.48 g in T_1. The lowest mean final weight of 221.08 g was observed in T_3. There was no significant ($p>0.05$) difference among the treatments. The highest mean final weight of *C. cirrhosus* was 289.27 g in T_1. The lowest mean final weight 217.53 g was in T_3. There was no significant ($p>0.05$) difference among the treatments. The highest mean final weight of *B. gonionotus* was 262.54 g in T_3. The lowest mean final weight 257.02 g was in T_2. There was no significant ($p>0.05$) difference among the treatments. The highest mean final weight of *O. niloticus* was obtained 456.56 g in T_3. The lowest mean final weight 439.41 g observed in T_2. There was no significant ($p>0.05$) difference among the treatments. The highest final weight was found in *H. molitrix* (1610.20±92.98g) in T_1 followed by other fishes and the lowest final weight in *C. cirrhosus* (217.53±8.63g) in T_3.

The mean range of weight gain was recorded 258.63 to 435.05 in *H. molitrix*, 162.78 to 221.18 g in *L. rohita*, 162.44 to 234.18 g in *C. cirrhosus,* 229.23 to 233.65 g in *B. gonionotus* and 438.82 to 455.97 g in *O. niloticus.* The mean weight gained by *H. molitrix, L. rohita, C. cirrhosus, B. gonionotus* and *O. niloticus* were 435.05, 221.18, 234.18, 233.65 and 443.89 g in T_1, 340.03, 206.70, 199.10, 229.23 and 438.82 g in T_2 and 258.63, 162.78, 162.44, 234.75 and 455.97 g in T_3 respectively. There was no significant ($p>0.05$) difference among the treatments. The specific growth rate of *H. molitrix* in different treatments ranged between 2.26 to 2.48%. The specific growth rate of *H. molitrix* was 2.48, 2.38 and 2.26% in T_1, T_2 and T_3 respectively. There was significant ($p<0.05$) difference among the treatments. The values of specific growth rate of *L. rohita* 2.20, 2.17 and 2.07% in T_1, T_2 and T_3, respectively. There was no significant ($p>0.05$) difference among the treatments. The values of specific growth rate of *C. cirrhosus* were 2.22, 2.16 and 2.07% in T_1, T_2 and T_3 respectively. There was significant ($p<0.05$) difference among the treatments.

The values of specific growth rate of *B. gonionotus* were 2.22, 2.16 and 2.22 % in T_1, T_2 and T_3, respectively. There was no significant ($p>0.05$) difference among the treatments. Specific growth rate of *O. niloticus* were 2.48, 2.50 and 2.48 % in T_1, T_2 and T_3, respectively. There was no significant ($p>0.05$) difference among the treatments. There were significant ($p<0.05$) difference among the treatments for *H. molitrix* and *C. cirrhosus* species. There were no significant ($p>0.05$) difference among the treatments for *L. rohita*, *B. gonionotus* and *O. niloticus* species.

Food conversion ratio (FCR) of the diet used for feeding fry were found 0.18, 0.23 and 0.17 in T_1, T_2 and T_3 respectively. Fries fed two times daily. There was no significant ($p>0.05$) difference among the treatments.

It was found that the production performance of each individual fish was not similar in the 3 treatments during study period. The species wise production of *H. molitrix* 6.51, *L. rohita* 6.67, *C. cirrhosus* 4.47, *B. gonionotus* 1.30, and *O. niloticus* 2.22 kg/dec/yr in T_1 ; *H. molitrix* 6.41, *L. rohita* 6.67, *C. cirrhosus* 5.92, *B. gonionotus* 0.83, and *O. niloticus* 2.20 kg/dec/yr in T_2 and *H. molitrix* 6.04, *L. rohita* 5.33, *C. cirrhosus* 5.03, *B. gonionotus* 1.50, and *O. niloticus* 2.24 kg/dec/yr in $T_{3,}$. The significantly ($p<0.05$) highest fish production was obtained 6.67±1.15 kg/dec/yr in T_1 and T_2 for *L. rohita*. The lowest fish production 0.83±0.59 kg/dec/yr was observed in T_3 for *O. niloticus*. The gross production of fish species was 20.37, 21.53 and 19.34 kg/dec/yr in T_1, T_2 and T_3 respectively. There was no significant ($p>0.05$) difference among the treatments. The net production of fish species was 15.01, 17.21 and 16.05 kg/dec/yr in T_1, T_2 and T_3, respectively. There was no significant ($p>0.05$) difference among the treatments. Details results were presented in table no 4.24.

Table 4.24: Growth and production performance of five fish species observed during the Paba Upazilla (Rajshahi University area)

Parameters	T_1	T_2	T_3
Initial weight (g)			
H. molitrix	67.80± 00	67.80± 00	67.80± 00
L. rohita	58.30± 00	58.30± 00	58.30± 00
C. cirrhosus	55.09±00	55.09±00	55.09±00
B. gonionotus	27.79±00	27.79±00	27.79±00
O. niloticus	0.59± 00	0.59± 00	0.59± 00
Final weight (g)			
H. molitrix	502.85± 21.32^{a}	407.83± 23.43^{a}	326.43± 28.32^{a}
L. rohita	279.48± 24.78^{a}	265.00± 24.78^{a}	221.08± 26.34^{a}
C. cirrhosus	289.27± 18.54^{a}	254.19± 17.62^{a}	217.53± 8.63^{a}
B. gonionotus	261.44± 3.82^{a}	257.02± 20.89^{a}	262.54± 14.73^{a}
O. niloticus	444.48± 15.11^{a}	439.41± 3.22^{a}	456.56± 7.73^{a}
Weight gain (g)			
H. molitrix	435.05± 13.69^{b}	340.03± 88.23^{a}	258.63± 38.11^{a}
L. rohita	221.18± 27.14^{a}	206.70± 34.74^{a}	162.78± 27.73^{a}
C. cirrhosus	234.18± 12.59^{a}	199.10± 31.53^{a}	162.44± 8.63^{a}
B. gonionotus	233.65± 27.75^{a}	229.23± 67.30^{a}	234.75± 24.34^{a}
O. niloticus	443.89± 14.17^{a}	438.82± 3.23^{a}	455.97± 22.15^{a}
Specific growth rate ((bwd^{-1})			
H. molitrix	2.48± 0.04^{a}	2.38± 0.13^{a}	2.26± 0.05^{a}
L. rohita	2.20± 0.05^{a}	2.17± 0.06^{a}	2.07± 0.07^{a}
C. cirrhosus	2.22± 0.02^{a}	2.16± 0.06^{a}	2.07± 0.02^{a}
B. gonionotus	2.22± 0.04^{a}	2.20± 0.11^{a}	2.22± 0.03^{a}
O. niloticus	2.48± 0.01^{a}	2.48± 0.05^{a}	2.50± 0.02^{a}
Survival rate (%)			
H. molitrix	93.16± 4.01^{a}	96.43± 4.50^{a}	98.55± 1.53^{a}
L. rohita	96.90± 2.06^{a}	98.61± 0.31^{a}	97.54± 3.00^{a}
C. cirrhosus	80.05± 4.71^{a}	93.45± 5.72^{a}	92.63± 12.75^{a}
B. gonionotus	95.81± 2.58^{a}	96.68± 2.07^{a}	100.00± 0.00^{b}
O. niloticus	95.20± 1.24^{a}	96.90± 1.15^{a}	100.00± 0.00^{b}
Food conversion ratio (FCR)	0.18 ± 0.04^{a}	0.23 ± 0.04^{a}	0.17 ± 0.03^{a}
Gross production (kg/dec/year)	20.37± 1.83^{a}	21.53± 1.37^{a}	19.34± 1.04^{a}
Gross production (kg/ha/year)	5033.39 ± 425.87 ^{a}	5319.69 ± 258.14^{a}	4777.08± 352.82^{a}
Net production (kg/dec/year)	16.05± 1.83^{a}	17.21± 1.05^{a}	15.01± 1.43^{a}
Net production (kg/ha/year)	3963.88± 425.87^{a}	4250.18± 258.14^{a}	3707.57± 352.82^{a}

The mean production of the five controlled pond of Paba Upazilla was 4.35 kg/ decimal. But the bottom layer polythene based model ponds per decimal production was 15.01 kg, 17.21 kg and 16.05 kg in T_1, T_2 and T_3 respectively which was higher than the controlled ponds. Results were shown in table 4.25.

Table 4.25: Production level of the five controlled pond during study period

Pond No.	Area (decimal)	Intial Weight (kg)	Gross production (kg)	Net Production (kg)	Net Production (kg/dec)
1	8.25	10	56.5	46.5	5.64
2	8.25	8	35.5	27.5	3.33
3	8.25	8	39	31	3.76
4	6.6	7	38	31	4.70
5	9.0	8	47	39	4.33
Average	8.07	8.2	43.2	35	4.35±0.89

4.2.1.2 Charghat Upazilla

The initial weight was recorded as 51.21g in *H. molitrix,* 51.13 g in *L. rohita,* 27.22 g in *C. cirrhosus,* 16.17 g in *B. gonionotus* and 0.59 g in *O. niloticus.* The mean range of final weight was recorded as 362.97g and 450.76g in *H. molitrix,* 221.72 g and 263.15 g in *L. rohita,* 204.39 g and 277.24 g in *C. cirrhosus* 249.50g and 357.77 g in *B. gonionotus* and 421.33g and 444.11 g in *O. niloticus.* There was significant ($p<0.05$) difference among the treatments.

Weight gain of all the five species of fishes varied considerably among the treatments. The mean range of weight gain was 311.47g to 398.14g in *H. molitrix,* 170.89 g to 211.23 g in *L. rohita,* 175.87 g to 248.74 g in *C. cirrhosus,* 322.65 g to 341.30 g in *B. gonionotus* and 421.01 g to 443.55 g in *O. niloticus.* The highest mean weight gain of *H. molitrix* was obtained 398.14 g in T_2. The lowest mean final weight was311.47 g observed in $T_{1.}$ There were significant ($p<0.05$) difference among the treatments.

The highest mean final weight of *L. rohita* was obtained 211.23 g in T_3. The lowest mean final weight was 170.89 g observed in $T_{1.}$ There was no significant ($p>0.05$) difference among the treatments. The highest mean final weight of *C. cirrhosus* was obtained 248.74 g in T_2. The lowest mean final weight was 175.87 g observed in $T_{1.}$

There was significant ($p<0.05$) difference among the treatments. The highest mean final weight of *B. gonionotus* was obtained 341.30 g in T_2. The lowest mean final weight was 322.65 g observed in T_3. There was no significant ($p>0.05$) difference among the treatments. The highest mean weight gain of *O. niloticus* was obtained 443.55 g in T_2. The lowest mean final weight 421.01 g observed in T_3. There was no significant ($p>0.05$) difference among the treatments.

The specific growth rate of fish species was 1.25% in T_1, 1.33% in T_2 and 1.33% in T_3.. There was significant ($p<0.05$) difference among the treatments.

Food conversion ratio (FCR) value of the diet used for feeding fry, at the rate of two times in a day were found as 0.40, 0.40 and 0.27 in T_1, T_2 and T_3 respectively.

The gross production of fish species was 17.86 kg/dec/yr in T_1, 21.67 kg/dec/yr in T_2 and 21.51 kg/dec/yr in T_3. There was no significant ($p>0.05$) difference among the treatments. The net production of fish species was 14.79 kg/dec/yr, 18.6 kg/dec/yr and 18.44 kg/dec/yr in T_1, T_2 and T_3, respectively. There was no significant ($p>0.05$) difference among the treatments. Details results were shown in table 4.26.

Table 4.26: Growth and production performance of five fish species observed during the Charghat Upazilla

Parameters	T_1	T_2	T_3
Initial weight (g)			
H. molitrix	51.21±0.00	51.21±0.00	51.21±0.00
L. rohita	51.13±0.00	51.13±0.00	51.13±0.00
C. cirrhosus	27.22±0.00	27.22±0.00	27.22±0.00
B. gonionotus	16.17±0.00	16.17±0.00	16.17±0.00
O. niloticus	0.59±0.00	0.59±0.00	0.59±0.00
Final weight (g)			
H. molitrix	$362.97±15.92^a$	$450.76±6.36^a$	$436.95±7.42^a$
L. rohita	$221.72±5.49^a$	$256.94±8.51^a$	$263.15±7.43^a$
C. cirrhosus	$204.39±9.42^a$	$277.24±8.92^a$	$242.22±3.42^a$
B. gonionotus	$249.50±9.43^b$	$357.77±9.32^{ab}$	$337.03±3.12^a$
O. niloticus	$427.50±6.32^a$	$444.11±8.32^a$	$421.33±5.42^a$
Weight gain (g)			
H. molitrix	$311.47±0.86^a$	$398.14±1.57^c$	$385.64±0.91^b$
L. rohita	$170.89±0.52^a$	$205.11±0.60^b$	$211.23±0.95^c$
C. cirrhosus	$175.87±1.17^a$	$248.74±2.67^c$	$215.87±0.90^b$
B. gonionotus	$232.84±0.79^a$	$341.30±0.70^c$	$322.65±1.89^b$
O. niloticus	$425.58±1.39^b$	$443.55±1.05^c$	$421.01±0.43^a$
Specific growth rate ((bwd^{-1})	$1.25±0.02^a$	$1.33±0.02^b$	$1.33±0.01^b$
Food conversion ratio (FCR)	$0.40±0.01^b$	$0.40±0.02^b$	$0.27±0.01^a$
Gross production (kg/dec/yr)	$17.86±1.77^a$	$21.67±2.34^a$	$21.51±7.64^a$
Gross production (kg/ha/yr)	$4414.45±354.72^a$	$5355.09±254.17^a$	$5315.55±261.15^a$
Net production (kg/dec/yr)	$14.79±1.83^a$	$18.6±1.05^a$	$18.44±1.43^a$
Net production (kg/ha/yr)	$3654.90±432.71^a$	$4596.50±232.62^a$	$4556.89±234.43^a$

Average net production of the five controlled pond was 4.32 kg/decimal in Charghat Upazilla. But per decimal production of the bottom layer digging based model ponds was 14.79±1.83 kg, 18.6±1.05 kg and 18.44±1.43 kg in T_1, T_2 and T_3 respectively which was higher than the controlled ponds. Production data of controlled ponds was presented in table 4.27.

Table 4.27: Production of five controlled ponds of Charghat Upazilla

Pond No.	Area (decimal)	Initial Weight (kg)	Gross production (kg)	Net Production (kg)	Net Production kg/dec
1	8.20	9	54.5	45.5	5.56
2	8.20	8	33.6	26.5	3.29
3	8.20	9	39	31	3.72
4	6.7	8	37	30	4.69
5	9.5	7	45	38	4.32
Average	8.16	8.20	41.82	34.20	4.32±0.88

4.2.1.3 Bogura Upazilla

The mean value of weight gain was recorded as 282.36 g, 286.36 g and 307.16 g in *H. molitrix*, 130.35 g, 119.44 g and 144.11 g in *L. rohita*, 144.96 g, 125.29 g and 143.44 g in *C. cirrhosus*, 197.03 g, 223.83 g, 211.57 g in *B. gonionotus* and 352.30 g, 411.73 g, 405.03 g in *O. niloticus* of three treatments respectively.

The specific growth rate of *H. molitrix* was 2.33, 2.32 and 2.28% in T_1, T_2 and T_3 respectively. The values of specific growth rate of *L. rohita* were 2.03% in T_1, 1.99% in T_2 and 2.06% in T_3. The specific growth rate of *C. cirrhosus* was 2.07, 2.01 and 2.07% in T_1, T_2 and T_3, respectively. Specific growth rate of *B. gonionotus* was 2.20, 2.25 and 2.23 % in T_1, T_2 and T_3. The specific growth rate of *O. niloticus* was 2.44% in T_1, 2.50% in T_2 and 2.50% in T_3.

Food conversion ratio (FCR) was found as 0.24, 0.38 and 0.17 in T_1, T_2 and T_3 respectively. The mean least FCR value 0.17 was found in T_3. The gross production of fish species was 16.13, 16.29 and 17.80 kg/dec/yr in T_1, T_2 and T_3 respectively. There was no significant (p>0.05) difference among the treatments. The net production of fish was 13.18, 13.35 and 14.83 kg/dec/yr in T_1, T_2 and T_3, respectively. There was no significant (p>0.05) difference among the treatments. Details results were presented in table 4.28.

Table 4.28: Growth and production performance of five fish species observed during the Bogra Sadar Upazilla

Parameters	T_1	T_2	T_3
Initial weight (g)			
H. molitrix	94.69± 00	94.14±00	91.72± 00
L. rohita	16.60± 00	16.69±00	20.33± 00
C. cirrhosus	10.12±00	11.27± 00	10.56± 00
B. gonionotus	38.57±00	36.37± 00	35.10± 00
O. niloticus	37.90± 00	38.07± 00	37.06± 00
Final weight (g)			
H. molitrix	377.05± 92.59^{a}	380.50± 177.97^{a}	398.88± 81.03^{a}
L. rohita	146.95± 10.48^{a}	136.13± 3.87^{a}	164.44± 42.29^{a}
C. cirrhosus	155.09± 20.60^{a}	136.55± 26.80^{a}	154.00± 19.63^{a}
B. gonionotus	235.60± 5.18^{a}	260.20± 21.76^{a}	246.67± 22.35^{a}
O. niloticus	390.20± 63.04^{a}	449.80± 117.35^{a}	442.09± 57.70^{a}
Weight gain (g)			
H. molitrix	282.36± 89.41^{a}	286.36± 165.19^{a}	307.16± 73.26^{a}
L. rohita	130.35± 13.21^{a}	119.44± 6.13^{a}	144.11± 37.08^{a}
C. cirrhosus	144.96± 21.36^{a}	125.29± 26.14^{a}	143.44± 18.65^{a}
B. gonionotus	197.03± 5.13^{a}	223.83± 23.80^{a}	211.57± 26.35^{a}
O. niloticus	352.30± 61.10^{a}	411.73± 118.58^{a}	405.03± 62.53^{a}
Specific growth rate (bwd^{-1})			
H. molitrix	2.33± 0.14^{a}	2.32± 0.22^{a}	2.28± 0.11^{a}
L. rohita	2.03± 0.05^{a}	1.99± 0.02^{a}	2.06± 0.11^{a}
C. cirrhosus	2.07± 0.06^{a}	2.01± 0.09^{a}	2.07± 0.06^{a}
B. gonionotus	2.20± 0.01^{a}	2.25± 0.05^{a}	2.23± 0.05^{a}
O. niloticus	2.44± 0.07^{a}	2.50± 0.13^{a}	2.50± 0.07^{a}
Survival rate (%)			
H. molitrix	87.27± 7.30^{a}	90.98± 4.60^{a}	85.83± 5.20^{a}
L. rohita	93.32± 1.87^{a}	94.42± 0.32^{a}	92.00± 2.00^{a}
C. cirrhosus	92.58± 1.01^{a}	93.36± 2.75^{a}	89.82± 3.27^{a}
B. gonionotus	80.50± 6.76^{a}	84.54± 1.16^{a}	77.78± 3.85^{a}
O. niloticus	78.67± 10.26^{a}	88.20± 3.65^{a}	80.89± 3.79^{a}
Food conversion ratio (FCR)	0.24 ± 0.13^{ab}	0.38 ± 0.06^{b}	0.17 ± 0.07^{a}
Gross production (kg/dec/8 months)	16.13± 2.68^{a}	16.29± 3.62^{a}	17.80± 3.78^{a}
Gross production (kg/ha/year)	3983.06 ± 662.84 ^{a}	4025.42 ± 892.76^{a}	4396.83± 834.21^{a}
Net production (kg/dec/year)	13.18± 2.67^{a}	13.35± 3.30^{a}	14.83± 3.20^{a}
Net production (kg/ha/year)	3255.81± 659.98^{a}	3295.79± 813.97^{a}	3663.84± 789.77^{a}

Average production of the five controlled pond was 5.14 kg/decimal in Bogura Sadar Upazilla. But per decimal production of the bottom layer compost based model ponds was 13.18± 2.67 kg, 13.35± 3.30 kg and 14.83± 3.20 kg in T_1, T_2 and T_3 respectively which was higher than the controlled ponds. Production details of controlled pond of Bogura Sadar Upazilla were presented in table 4.29.

Table 4.29: Production level of the five controlled pond during study period at Bogura Sadar upazila

Pond No.	Area (decimal)	Intial Wt. (kg)	Gross production (kg)	Net Production (kg)	Net Production (kg/d)
1	10	30	80	50	5.00
2	16	15	60	45	2.81
3	5	20	75	55	11.00
4	17	25	80	55	3.24
5	15	35	90	55	3.67
Average	**12.6**	**25**	**77**	**52**	**5.14±3.37**

4.2.1.4 Monthly variation of production (Kg/decimal) of cultured species

Among the 8 months of cultured period production per decimal is increasing after month to month. No significant ($p>0.05$) difference was observed in the production May, June, July, August and December where significant ($p<0.05$) difference was found in the month September, October and November in the model ponds of three study areas. Monthly production (kg/decimal) of cultured species in the Paba, Charghat and Bogura Upazila are presented in the table 4.30, 4.31 and 4.32 respectively.

Table 4.30: Monthly productions (Kg/decimal) of cultured species in the Paba Upazilla

Name of month	T_1 (Mean±SD)	T_2 (Mean±SD)	T_3 (Mean±SD)
May	$4.33±0.0^a$	$4.33±0.0^a$	$4.33±0.0^a$
June	$7.36±0.4^a$	$6.96±1.120^a$	$6.28±0.12^a$
July	$9.59±1.12^a$	$9.56±2.29^a$	$8.05±1.10^a$
August	$11.23±1.43^a$	$10.76±1.56^a$	$9.75±1.38^a$
September	$14.85±0.55^a$	$15.74±0.65^b$	$13.66±1.11^a$
October	$15.53±0.42^a$	$16.95±0.88^b$	$14.47±1.23^a$
November	$17.17±0.37^{ab}$	$19.15±1.17^b$	$16.25±1.14^a$
December	$20.37±1.83^a$	$21.53±1.37^a$	$19.34±1.04^a$

Values in the same row having same superscript letters are not significantly different ($p > 0.05$)

Table 4.31: Production (Kg/decimal) of cultured species in ponds in study pond of Charghat Upazila

Name of species	T_1 (Mean±SD)	T_2 (Mean±SD)	T_3 (Mean±SD)
May	3.07±0.0[a]	3.07±0.0[a]	3.07±0.0[a]
June	5.70±0.40[a]	6.32±1.36[a]	5.77±0.40[a]
July	8.62±0.21[a]	11.23±1.36[b]	10.91±0.23[b]
August	10.26±2.11[a]	12.92±1.22[a]	11.37±0.32[a]
September	12.68±1.5[a]	13.51±1.64[a]	13.18±0.67[a]
October	14.61±1.88[a]	16.66±3.43[a]	15.79±4.21[a]
November	15.96±1.43[a]	19.95±4.33[a]	20.62±2.30[a]
December	17.86±1.77[a]	21.67±2.34[a]	21.51±7.64[a]

Values in the same row having different superscript letters are significantly different ($p < 0.05$)

Table 4.32: Monthly productions (Kg/decimal) of cultured species in the Bogura Sadar Upazila

Name of month	**T_1** (Mean±SD)	**T_2** (Mean±SD)	**T_3** (Mean±SD)
May	2.95±0.50[a]	2.96±0.34[a]	2.97±0.43[a]
June	4.01±0.81[a]	4.22±1.12[a]	4.08±0.98[a]
July	5.05±1.05[a]	4.98±1.08[a]	5.10±1.07[a]
August	5.93±0.99[a]	6.76±1.31[a]	6.28±1.28[a]
September	11.17±2.10[a]	10.60±2.50[a]	11.94±2.52[a]
October	13.10±3.16[a]	12.57±4.04[a]	12.37±3.13[a]
November	14.11±2.92[a]	14.17±4.09[a]	15.37±3.50[a]
December	16.13±2.68[a]	16.29±3.62[a]	17.80±3.38[a]

Values in the same row having same superscript letters are not significantly different ($p > 0.05$)

4.2.1.5 Comparison of growth performances among three upazillas and control ponds at 2017

Production of each area was higher than control ponds. Average net production of RU area was 16.09 Kg/dec, in Charghat 17.27 Kg/dec and in Bogura it was 13.86Kg/dec in 2017. Net production (kg/dec) of RU was 2.19% higher than average net production (kg/dec) of control ponds. Thus net production (kg/dec) of Charghat and Bogura Sadar Upazilla were 3.7% and 3.01% higher than control ponds respectively. Details are presented in table 4.33below:

Table 4.33: Growth performances of three study areas and control ponds at 2017

Treatments	Average Intial Wt. (kg/dec)	Average Gross production (kg/dec)	Average Net Production (kg/dec)
RU Area	4.32	20.41	16.09
Charghat	3.06	20.34	17.27
Bogura	2.95	16.74	13.86
Control ponds	0.98	5.59	4.60

Average fish production of five control pond was 4.35 kg/decimal in the study period whereas at the same time the bottom layered polythene based model ponds was increased 268.97%, 295.63% and 245.06% for for $T_{1,}$ T_2 and T_3 respectively against the control ponds. Again the average fish production of five control ponds of Charghat upazila was 4.32 kg/decimal whereas at the same time the digging based model ponds of Charghat upazila, it was increased 242.36%, 330.56% and 326.85% for $T_{1,}$ T_2 and T_3 respectively against the control pond. However, for Bogura sadar Upazila the average fish production of five control ponds was 5.14 kg/decimal whereas at the same time the compost based model ponds of Bogura sadar upazila, it was increased 156.42%, 159.73% and 188.52% for $T_{1,}$ T_2 and T_3 respectively against the control ponds.

4.2.2 Growth performance of 2018

Growth performances of three study areas studied as previous year. Weight and length was monitored fortnightly. Details are presented below:

4.2.2.1 Rajshahi University Area

In the year 2018 the mean final weight of *H. molitrix* was 454.59±84.80gm, 416.44±15.95gm and 408.44±27.50 gm in T_1, T_2 and T_3, respectively. The maximum mean final weight of *H. molitrix* was observed in T_1 and the minimum final weight was observed in T_3. In case of *L. rohita* the mean final weight was 302.61±15.85 gm 301.41±11.34 gm and 294.79±21.31gm in in T_1, T_2 and T_3. The maximum mean final weight of was observed in T_1 and the minimum final weight was observed in T_3. The mean final weight of *C. cirrhosus* was 293.83±10.35 gm, 292.43±10.85 gm and 302.28±35.15 gm in T_1, T_2 and T_3 respectively. The maximum mean final weight of *C. cirrhosus* was observed in T_3 and the minimum final weight was observed in T_2. In T_1, T_2 and T_3, the mean final weight of *B. gonionotus* was 401.97±52.62 gm 415.67±29.35 gm and 380.86±65.73 gm. The maximum mean final weight of *B. gonionotus* was observed in T_3 and the minimum final weight was observed in T_2. The mean final weight of *O. niloticus* was 394.76±5.27 gm in T_1, 395.80±5.59 gm in T_2, and 372.80±12.81gm in T_3.

The mean weight gain of *H. molitrix* was 395.93±84.83gm in T_1, 357.77±15.95gm in T_2 and 350.18±27.44gm in T_3. The mean weight gain of *L. rohita* was recorded as 250.84±15.86 gm, 249.64±11.33 gm and 243.01±21.32 gm in T_1, T_2 and T_3 respectively. There was no significant ($p>0.05$) difference among the treatments. In case of *C. cirrhosus* the mean weight gain was 237.37±10.35 gm, 235.97±10.85 gm and 245.82±35.16 gm in T_1, T_2 and T_3, respectively. The mean weight gains of *B. gonionotus* 393.79±52.61 gm 407.51±29.30 gm and 372.55±65.51 gm in T_1, T_2 and T_3 respectively. The mean weight gains of *O. niloticus* 387.49±5.26 gm, 388.43±5.72 gm and 365.42±12.87 gm in T_1, T_2 and T_3 respectively. The specific growth rate of *H. molitrix* was 0.83± 0.07, 0.80±0.01and 0.79±0.02% in T_1, T_2 and T_3 respectively. The specific growth rate of *L. rohita* was 0.72±0.02, 0.72±0.01and 0.70± 0.03% in T_1, T_2 and T_3 respectively. The specific growth rate of *C. cirrhosus* was 0.67± 0.01% in T_1, 0.67±0.01% in $T_2$and 0.68±0.04 in T_3. The specific growth rate of *B. gonionotus* was 1.59± 0.05, 1.60±0.02 and 1.55± 0.06 % in T_1, T_2 and T_3 respectively. The specific growth rate of *O. niloticus* was 1.63±0.01% in T_1, 1.62±0.01 % in T_2 and 1.60±0.02% in T_3 respectively. There was no significant ($p>0.05$) difference among the treatments of five fish species. Food conversion ratio (FCR) value of the diet used for feeding fry, at the rate of two times in a day were found as 1.14, 1.47 and 1.12 in T_1, T_2 and T_3 respectively. There was no significant (p>0.05) difference among the treatments. The gross production of fish species was 21.19±1.27, 20.53±0.69 and 20.26 ±0.84 kg/dec/year in T_1, T_2 and T_3 respectively. There was no significant (p>0.05) difference among the treatments. The net production of fish species was 18.11±1.28, 17.44±0.69 and 17.19±0.85 kg/dec/year in T_1, T_2 and T_3 respectively. There was no significant (p>0.05) difference among the treatments. Details results are presented in table 4.34.

Table 4.34: Growth performance of fish species observed during the study period at Rajshahi University area (Paba Upazila)

Growth parameters	Fish species	T_1	T_2	T_3
Initial weight (g)	*H. molitrix*	$58.66±0.034^a$	$58.67±0.017^a$	$58.25±0.375^a$
	L. rohita	$51.77±0.010^a$	$51.77±0.005^a$	$51.77±0.011^a$
	C. cirrhosus	$56.45±0.005^a$	$56.46±0.001^a$	$56.45±0.005^a$
	B. gonionotus	$8.16±0.288^a$	$8.13±0.057^a$	$8.30±0.264^a$
	O. niloticus	$7.27±0.144^a$	$7.36±0.123^a$	$7.37±0.075^a$
Final weight (g)	*H. molitrix*	$454.59±84.80^a$	$416.44±15.95^a$	$408.44±27.50^a$
	L. rohita	$302.61±15.85^a$	$301.41±11.34^a$	$294.79±21.31^a$
	C. cirrhosus	$293.83±10.35^a$	$292.43±10.85^a$	$302.28±35.15^a$
	B. gonionotus	$401.97±52.62^a$	$415.67±29.35^a$	$380.86±65.73^a$
	O. niloticus	$394.76±5.27^b$	$395.80±5.59^b$	$372.80±12.81^a$
Weight gain (g)	*H. molitrix*	$395.93±84.83^a$	$357.77±15.95^a$	$350.18±27.44^a$
	L. rohita	$250.84±15.86^a$	$249.64±11.33^a$	$243.01±21.32^a$
	C. cirrhosus	$237.37±10.35^a$	$235.97±10.85^a$	$245.82±35.16^a$
	B. gonionotus	$393.79±52.61^a$	$407.51±29.30^a$	$372.55±65.51^a$
	O. nilotic us	$387.49±5.26^b$	$388.43±5.72^b$	$365.42±12.87^a$
Specific growth rate (%bwd^{-1})	*H. molitrix*	$0.83±0.07^a$	$0.80±0.01^a$	$0.79±0.02^a$
	L. rohita	$0.72±0.02^a$	$0.72±0.01^a$	$0.70±0.03^a$
	C. cirrhosus	$0.67±0.01^a$	$0.67±0.01^a$	$0.68±0.04^a$
	B. gonionotus	$1.59±0.05^a$	$1.60±0.02^a$	$1.55±0.06^a$
	O. niloticus	$1.63±0.01^a$	$1.62±0.01^a$	$1.60±0.02^a$
Food conversion ratio (FCR)		$1.14±0.25^a$	$1.47±0.30^a$	$1.11±0.26^a$
Gross production (kg/dec/year)		$21.19±1.27^a$	$20.53±0.69^a$	$20.26±0.84^a$
Net production (kg/dec/year)		$18.11±1.28^a$	$17.44±0.69^a$	$17.19±0.85^a$
Net production (kg/ha/year)		$4474.55±317.10^a$	$4309.78±172.10^a$	$4246.76±209.95^a$

Values in the same row having different superscript letters are significantly different ($p < 0.05$)

The production data of five control ponds in Paba upazila was collected from five pond owner of this area. Per decimal net production were 5.50, 4.24, 5.88, 5.58 and 4.44 kg for pond 1,2,3,4 and 5 respectively. The average net production of five ponds was 5.13±0.74 kg/dec. Details are presented below in table 4.35:

Table 4.35: Production level of the five controlled pond during study period at Paba upazila on 2018

Pond No.	Area (decimal/Pond)	Intial Wt. (kg/ Pond)	Gross production (kg/ Pond)	Net Production (kg/ Pond)	Net Production (kg/d)
1	8.25	15	60.4	45.4	5.50
2	8.25	10	45	35	4.24
3	8.25	7	55.5	48.5	5.88
4	6.6	8	44.8	36.8	5.58
5	9	9	49	40	4.44
Average	8.07	9.8	50.94	41.14	5.13±0.74

4.2.2.2 Charghat Upazilla

The mean final weight of *H. molitrix* was 402.03±107.42 gm, 432.66±59.74 gm and 370.40±102.31 gm in T_1, T_2 and T_3 respectively. In case of *L. rohita* the mean final weight was 333.60±71.72 gm in $T_{1,}$ 269.50±35.28 gm in T_2 and 291.83±51.34 gm in $T_{3.}$ The mean final weight of *C. cirrhosus* was 232.20±4.92 gm, 229.10±17.24 gm and 220.20±15.69 gm in T_1, T_2 and T_3 respectively. In T_1, T_2 and $T_{3,}$ the mean final weight of *B. gonionotus* was 269.86±45.09 gm 309.10±46.32 gm and 265.53±19.97 gm respectively. The mean final weight of *O. niloticus* was 310.50±27.62 gm in T_1, 297.70±9.79 gm in T_2, and 273.00±34.83 gm in T_3.

Weight gain of all the five species of fishes varied considerably among the treatments. The mean weight gain of *H. molitrix* was 343.35±107.42 gm, 373.98±59.74 gm and 311.72±102.31 gm in T_1, T_2 and T_3 respectively. The mean weight gain of *L. rohita* was recorded as 281.82±71.72 gm in T_1, 217.72±35.28 gm in T_2 and 240.05±51.34 gm in T_3, respectively. There was no significant (p>0.05) difference among the treatments. In case of *C. cirrhosus* the mean weight gain was 175.74±4.92 gm, 172.64±17.24 gm and 163.74±15.69 gm in T_1, T_2 and T_3 respectively. There was no significant (p>0.05) difference among the treatments. The mean weight gains of *B.*

gonionotus 261.72±45.09 gm 300.96±46.32 gm and 257.39±19.97 gm in T_1, T_2 and T_3, respectively. There was no significant (p>0.05) difference among the treatments. The mean weight gain of *O. niloticus* 303.07±27.62 gm in T_1, 290.27±9.79 gm in T_2 and 265.57±34.83 gm in T_3. The highest mean weight gain was in T_1 and the lowest mean weight gain was observed in T_3. There was significant (p<0.05) difference among the treatments.

The specific growth rate of *H. molitrix* was 0.77± 0.11, 0.81±0.05 and 0.74±0.10 in T_1, T_2 and T_3, respectively. The specific growth rate of *L. rohita* was 0.75±0.08 % in T_1, 0.67±0.04% in T_2 and 0.70± 0.07% in T_3. The specific growth rate of *C. cirrhosus* was 0.58± 0.10%, 0.57±0.03% and 0.55±0.03% in T_1, T_2 and T_3 respectively. The specific growth rate of *B. gonionotus* was 1.42± 0.07% in T_1, 1.48±0.06% in T_2 and 1.42± 0.03% in T_3. The specific growth rate of *O. niloticus* was 1.52±0.03%, 1.50±0.01% and 1.47±0.05% in T_1, T_2 and T_3 respectively. There was no significant (p>0.05) difference among the treatments of five fish species.

Food conversion ratio (FCR) value of the diet used for feeding fry, at the rate of two times in a day were found as 1.37±0.31, 1.59±0.45 and 1.04±0.13 in T_1, T_2 and T_3 respectively. There was no significant (p>0.05) difference among the treatments.

The gross production of fish species was 19.06±2.05, 18.39±1.37 and 17.41±2.79 kg/dec/year in T_1, T_2 and T_3 respectively. The net production of fish species was 15.97±2.05, 15.29±1.38 and 14.38±2.89 kg/dec/year in T_1, T_2 and T_3 respectively. There was no significant (p>0.05) difference among the treatments.Results are showed in the table 4.36.

Table 4.36: Growth performance of fish species observed during the study period at Charghat Upazila.

Growth parameters	Fish species	T_1	T_2	T_3
Initial weight (g)	*H. molitrix*	58.88±0.00[a]	58.88±0.0[a]	58.88±0.00[a]
	L. rohita	51.78±0.00[a]	51.78±0.00[a]	51.78±0.00[a]
	C. cirrhosus	56.46±0.00[a]	56.46±0.00[a]	56.46±0.00[a]
	B. gonionotus	8.14±0.00[a]	8.14±0.00[a]	8.14±0.00[a]
	O. niloticus	7.43±0.00[a]	7.43±0.100[a]	7.43±0.00[a]
Final weight (g)	*H. molitrix*	402.03±107.42[a]	432.66±59.74[a]	370.40±102.31[a]
	L. rohita	333.60±71.72[a]	269.50±35.28[a]	291.83±51.34[a]
	C. cirrhosus	232.20±4.92[a]	229.10±17.24[a]	220.20±15.69[a]
	B. gonionotus	269.86±45.09[a]	309.10±46.32[a]	265.53±19.97[a]
	O. niloticus	310.50±27.62[a]	297.70±9.79[a]	273.00±34.83[a]
Weight gain (g)	*H. molitrix*	343.35±107.42[a]	373.98±59.74[a]	311.72±102.31[a]
	L. rohita	281.82±71.72[a]	217.72±35.28[a]	240.05±51.34[a]
	C. cirrhosus	175.74±4.92[a]	172.64±17.24[a]	163.74±15.69[a]
	B. gonionotus	261.72±45.09[a]	300.96±46.32[a]	257.39±19.97[a]
	O. niloticus	303.07±27.62[a]	290.27±9.79[a]	265.57±34.83[a]
Specific growth rate ((bwd^{-1})	*H. molitrix*	0.77± 0.11[a]	0.81±0.05[a]	0.74±0.10 [a]
	L. rohita	0.75±0.08[a]	0.67±0.04[a]	0.70± 0.07[a]
	C. cirrhosus	0.58± 0.10[a]	0.57±0.03[a]	0.55±0.03 [a]
	B. gonionotus	1.42± 0.07[a]	1.48±0.06[a]	1.42± 0.03[a]
	O. niloticus	1.52±0.03[a]	1.50±0.01[a]	1.47±0.05[a]
Food conversion ratio (FCR)		1.37±0.31 [a]	1.59±0.45[a]	1.04±0.13 [a]
Gross production (kg/dec/year)		19.06±2.05[a]	18.39±1.37[a]	17.41±2.79[a]
Gross production (kg/ha/year)		4708.71±506.54[a]	4543.17±340.59[a]	4300.82±688.9[a]
Net production (kg/dec/year)		15.97±2.05a	15.29±1.38a	14.38±2.89a
Net production (kg/ha/year)		3945.58±507.84[a]	3778.40±342.49[a]	3552.19±714.9[a]

Values in the same row having different superscript letters are significantly different ($p < 0.05$)

The production data of five control ponds in Charghat upazila was collected from five fish farmers of this region. Per decimal net production was 2.08, 4.82, 4.75, 10.80 and 3.00 kg for pond 1,2,3,4 and 5 respectively. The average net production of five ponds was 5.09±3.40 kg/dec. Details are given in the table 4.37.

Table 4.37: Fish production of five controlled pond during study period (2018) at Charghat upazila

Pond No.	Area (decimal/Pond)	Intial Wt. (kg/ Pond)	Gross production (kg/ Pond)	Net Production (kg/ Pond)	Net Production (kg/d)
1	12	19	44	25	2.08
2	5	5.9	30	24.1	4.82
3	12	13	70	57	4.75
4	5	24	78	54	10.80
5	14	13	55	42	3.00
Average	9.6	14.98	55.4	40.42	5.09±3.40

4.2.2.3 Bogura Upazilla

The mean final weight of *H. molitrix* was 532.46±19.64 gm, 582.83±78.62 gm and 565.87±85.38 gm in T_1, T_2 and T_3 respectively. In case of *L. rohita* the mean final weight was 322.90±20.91 gm in $T_{1,}$ 311.83±29.11 gm in T_2 and 317.62±19.91 gm in$T_{3.}$ The mean final weight of *C. cirrhosus* was 187.67±123.66 gm, 190.87±126.33 gm and 118.58±127.45 gm in T_1, T_2 and T_3 respectively. In T_1, T_2 and T_3 the mean final weight of *B. gonionotus* was 392.87±6.47, gm 401.03±12.93 gm and 396.03±9.29 gm repectively. The mean final weight of *O. niloticus* was 351.67±3.72 gm, 311.73±10.85 gm, and 304.47±3.48 gm in T_1, T_2 and T_3 respectively.

The mean weight gain of *H. molitrix* was 480.73±0.69 gm, 529.95±8.23 gm and 512.82±9.11 gm in T_1, T_2 and T_3 respectively. The mean weight gain of *L. rohita* was recorded as 269.97±1.14 gm in T_1, 295.08±4.74 gm in $T_2$and 264.99±1.73 gm in T_3. There was no significant (p>0.05) difference among the treatments. In case of *C. cirrhosus* the mean weight gain was 136.39±0.59 gm, 139.090±3.63 gm and 67.60±12.63 gm in T_1, T_2 and T_3 respectively. The mean weight gains of *B. gonionotus* 386.67±29.75 gm in $T_{1,}$ 394.83±7.10 gm in $T_2$and 389.73±2.34 gm in T_3. The mean weight gain of *O. niloticus* was found 345.17±0.17 gm in T_1, 304.83±3.23 gm in $T_2$and 297.73±3.11 gm in T_3. There was significant (p<0.05) difference among the treatments.

The specific growth rate of *H. molitrix* was 2.28±0.01, 2.28±0.13 and 2.16±0.05 in T_1, T_2 and T_3 respectively. There was no significant (p>0.05) difference among the treatments. The specific growth rate of *L. rohita* was 2.00±0.05%, 2.07±0.06% and

2.07±0.07% in T_1, T_2 and T_3 respectively. The specific growth rate of *C. cirrhosus* was 2.02±0.02%, 2.06±0.06% and 2.07±0.02% in T_1, T_2 and T_3 respectively. The specific growth rate of *B. gonionotus* was 2.02±0.04% in T_1, 2.10±0.11% T_2 and 2.17±0.03 in % T_3. The specific growth rate of *O. niloticus* was 2.28±0.01%, 2.28±0.05% and 2.25±0.02% in T_1, T_2 and T_3 respectively.. There was no significant (p>0.05) difference among the treatments.

Food conversion ratio (FCR) value of the diet used for feeding fry, at the rate of two times in a day were found as 0.19±0.04, 0.25±0.04 and 0.18±0.03 in T_1, T_2 and T_3 respectively. The mean lowest FCR value was found in T_3. The highest mean FCR value was found in T_2 where fry fed two times daily. There was no significant (p>0.05) difference among the treatments.

The gross production of fish species was 18.20±1.83, 17.91±1.37 and 17.87±1.04 kg/dec/year in T_1, T_2 and T_3 respectively. The net production of fish species was 14.50±1.83, 14.17 ±1.05 and 14.15±1.43 kg/dec/year in T_1, T_2 and T_3 respectively. There was no significant (p>0.05) difference among the treatments. Details results are shown in table 4.38.

Table 4.38: Growth performance of fish species observed during the study period at Bogura Sadar upazila

Growth parameters	Fish species	T_1	T_2	T_3
Initial weight (g)	*H. molitrix*	51.73±0.91	52.88±0.28	53.05±0.71
	L. rohita	52.93±1.73	52.75±1.06	52.63±0.50
	C. cirrhosus	51.28±0.68	51.78±1.07	50.98±0.60
	B.gonionotus	6.20±0.26	6.20±0.78	6.30±0.26
	O. niloticus	6.50±0.46	6.90±0.72	6.74±0.51
Final weight (g)	*H. molitrix*	532.46±19.64^{a}	582.83±78.62^{a}	565.87±85.3
	L. rohita	322.90±20.91^{a}	311.83±29.11^{a}	317.62±19.9
	C. cirrhosus	187.67±123.66^{a}	190.87±126.33	118.58±127.
	B.gonionotus	392.87±6.47^{a}	401.03±12.93^{a}	396.03±9.29
	O. niloticus	351.67±3.72^{a}	311.73±10.85^{a}	304.47±3.48
Weight gain (g)	*H. molitrix*	480.73±0.69^{b}	529.95±8.23^{ab}	512.82±9.11
	L. rohita	269.97±1.14^{a}	295.08±4.74^{a}	264.99±1.73
	C. cirrhosus	136.39±0.59^{b}	139.09±3.63^{ab}	67.60±12.63
	B.gonionotus	386.67±29.75^{a}	394.83±7.10^{a}	389.73±2.34
	O. niloticus	345.17±0.17^{a}	304.83±3.23^{a}	297.73±3.11
Specific growth rate ((bwd^{-1})	*H. molitrix*	2.28±0.01b	2.28±0.13ab	2.16±0.05a
	L. rohita	2.00±0.05a	2.07±0.06a	2.07±0.07a
	C. cirrhosus	2.02±0.02a	2.06±0.06b	2.07±0.02b
	B.gonionotus	2.02±0.04a	2.10±0.11a	2.17±0.03a
	O. niloticus	2.28±0.01a	2.28±0.05a	2.25±0.02a
Initial weight (Kg/d)		3.70±0.06^{a}	3.74±0.05^{a}	3.72±0.04^{a}
Food conversion ratio (FCR)		0.19±0.04a	0.25±0.04a	0.18±0.03a
Gross production (kg/dec/ year)		18.20±1.83^{a}	17.91±1.37^{a}	17.87±1.04^{a}
Gross production (kg/ha/ year)		4513.6±11.10^{a}	4429.24±198.1	4416.71±219
Net production (kg/dec/ year)		14.50±1.83^{a}	14.17 ±1.05^{a}	14.15±1.43^{a}
Net production (kg/ha/ year)		3583.79±415.8	3502.22±198.1	3497.28±292

The production data of five control ponds in Bogura sadar upazila was collected from five pond owner in this area. Per decimal net production was 5.63, 3.21, 11.25, 3.33 and 3.00 kg for pond 1,2,3,4 and 5 respectively. The average net production of five ponds was 5.28±3.50 kg/dec. Data was presented in table 4.39 below.

Table 4.39: Fish production of 5 controlled ponds during study period (2018) at Bogura sadar upazila

Pond No.	Area (decimal/ Pond)	Intial Wt. (kg/ Pond)	Gross production (kg/ Pond)	Net Production (kg/ Pond)	Net Production (kg/d)
1	8	30	75	45	5.63
2	14	15	60	45	3.21
3	4	20	65	45	11.25
4	16.5	25	80	55	3.33
5	15	35	80	45	3.00
Average	**11.50**	**25.00**	**72.00**	**47.00**	**5.28±3.50**

4.2.2.4 Fish production of model ponds and controlled ponds of three upazilas at 2018

Per decimal average net production was 18.11 kg, 17.45 kg and 17.19 Kg for $T_{1,}$ T_2 and T_3 respectively to the polythene based model ponds at Paba upazila but the average production of 5 controlled ponds was 5.13 kg/d which was 3.53, 3.40 and 3.35 times better than control ponds. In Charghat upazila average net production was 15.97 kg, 15.30 kg and 14.38 Kg/ d for $T_{1,}$ T_2 and T_3 respectively whereas per decimal production of controlled ponds was 5.09 kg which was 3.14, 3.01 and 2.83 times better than control ponds. However, at Bogura sadar upazila the net production was 14.50, 14.17 and 14.15 Kg/ d for $T_{1,}$ T_2 and T_3 respectively but the average production of 5 controlled ponds was 5.28 kg/d which was 2.75, 2.68 and 2.67 times better than control ponds. (Table 4.40).

Table 4.40: Net fish production (kg/d) of model ponds in the study period at three upazilas on 2018

Location	Mean fish production (Kg/ decimal)			Controlled ponds
	T_1 (8 feet)	T_2 (7 feet)	T_3 (6 feet)	
Paba	18.11	17.45	17.19	5.13
Charghat	15.97	15.30	14.38	5.09
Bogura	14.50	14.17	14.15	5.28

Average net fish production of five control pond was 5.13 kg/decimal in the study period whereas at the same time the bottom layered polythene based model ponds at Paba upazila was increased 253.02%, 240.16% and 235.09% for $T_{1,}$ T_2 and T_3

respectively against the control ponds. Again the average net fish production of five control ponds of charghat upazila was 5.09 kg/decimal whereas at the same time the digging based model ponds of charghat upazila, it was increased 213.75%, 200.59% and 182.51% for $T_{1,}$ T_2 and T_3 respectively against the control pond. However, at Bogura sadar Upazila the average net fish production of five control ponds was 5.28 kg/decimal whereas at the same time the compost based model ponds of Bogura sadar upazila, it was increased 174.62%, 168.37% and 167.99% for $T_{1,}$ T_2 and T_3 respectively against the control ponds.

4.2.2.5 Comparison of growth performances among three upazillas and control ponds at 2018

Production of each study area was higher than control ponds. Average net production of RU area was 17.58 Kg/dec, in Charghat 16.21 Kg/dec and in Bogura it was 14.27Kg/dec in 2018.Average net production of control pond was 4.48 kg/dec. Net production (kg/dec) of RU was 3.92% higher than average net production (kg/dec) of control ponds. Thus net production (kg/dec) of Charghat and Bogura Sadar Upazilla were 3.61% and 3.18% higher than control ponds respectively. Details are presented in table 4.41 below:

Table 4.41: Growth performances of three study areas and control ponds at 2018

Treatments	Average Intial Wt. (kg/dec)	Average Gross production (kg/dec)	Average Net Production (kg/dec)
RU Area	3.08	20.66	17.58
Charghat	2.06	18.28	16.21
Bogura	3.71	17.99	14.27
Control ponds	1.6	6.11	4.48

4.3 Assessment of water quality parameter of the research ponds.

Regular monitoring of water quality is very important for fish culture. Parameters should be in suitable range to get much production. Physical, chemical and biological parameters were monitored in three study areas. Water quality of given parameters of 2017 are given below:

4.3.1 Physical parameters of three study areas at 2017

Mean values of water temperature in T_1,T_2 and T_3 of Paba Upazila (RU campus) were

27.69±3.91 ^{0}C, 28.06±3.91 ^{0}C and 28.44±3.88 ^{0}C respectively. Maximum temperature was recorded in the month of August and minimum was in December. The mean values of transparency of Paba Upazila (RU campus) were 25.63±0.33 cm, 27.50±0.83 cm and 27.69±1.66 cm in T_1,T_2 and T_3 respectively.

The mean values of water temperature in treatments T_1,T_2 and T_3 were 29.21±0.83, 28.69±0.69 and 29.42±0.92°C respectively in Charghat upazila. Maximum temperature was recorded in the month of September and minimum was in December. The mean values of transparency content of the water in treatment T1, T2 and T3 were 25.98±0.48, 25.97±0.46 and 27.85±0.86 cm, respectively.

The mean values of water temperature in treatments T_1, T_2 and T_3 were 26.69±1.90°C, 27.06±1.80 °C and 29.44±2.21 °C of Bogra Sadar upazila. Maximum temperature was recorded in the month of August and minimum was in January. The mean values of transparency of the water 22.63±0.21cm in T_1, 24.50±1.02 cm T_2 and 20.60±1.60 cm inT_3.Variations of physical parameters in three study areas are presented in fig 4.3.

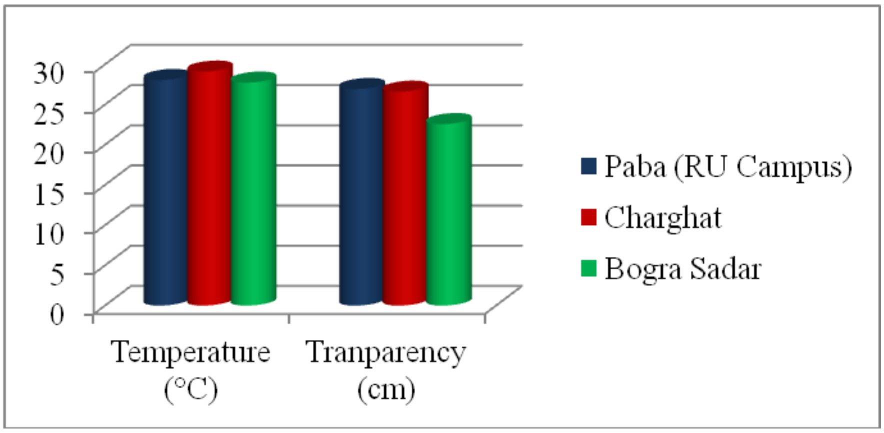


Fig 4.3. Variations of physical factors in three study areas during 2017

4.3.2 Chemical parameters of three study areas at 2017

At Paba Upazila (RU Campus) the mean values of pH content of the water in T_1, T_2 and T_3 were 7.38±0.18, 7.47±0.15 and 7.72±0.34 respectively. The mean values of dissolved oxygen of this area were 6.00±0.5 mg/l, 6.31±0.86 mg/l and 7.38±0.65 mg/l in T_1, T_2 and T_3 respectively. The mean values of carbon di-oxide content of the water were 2.06±0.32 mg/l in T_1, 1.81±0.39 mg/l in T_2 and 2.29±0.13 mg/l T_3. The mean values of nitrate content of the water in treatment T_1, T_2 and T_3 were 0.77±0.31 mg/l, 0.62±0.30 mg/l and 0.69±0.21 mg/l respectively in Paba Upazila (RU Campus). The mean values of phosphate-phosphorus were 1.30±0.10 mg/l in T_1, 0.95±0.20 mg/l T_2 and 0.63±0.18 mg/l in T_3. In this study area the mean values of ammonia were found T_1, T_2 and T_3 0.35±0.07 mg/l, 0.32±0.05 mg/l and 0.21±0.05 mg/l respectively. The mean values of alkalinity of this area were 164.89±8.69 mg/l, 158.81±1.61 mg/l and 178.29±2.56 mg/l in T_1, T_2 and T_3 respectively.

The mean values of pH content of the water in T_1, T_2 and T_3 were 7.35±0.10, 7.44±0.09 and 7.55±.13, respectively in Charghat Upazila. The mean values of dissolved oxygen of this area were 6.12±0.13 mg/l, 6.36±0.15 mg/l and 6.37±0.05 mg/l in T_1, T_2 and T_3 respectively. The mean values of carbon di-oxide content of the water were 2.18±0.17 mg/l in T_1, 1.84±0.11 mg/l in T_2 and 2.33±0.08 mg/l T_3. The mean values of nitrate content of the water in treatment T_1, T_2 and T_3 were 0.83±0.02, 0.58±0.02 and 0.72±0.02 mg/l respectively in Charghat Upazila. The mean values of phosphate-phosphorus were 4.60±0.10 mg/l in T_1, 4.47±0.17 mg/l in T_2 and 4.42±0.06 mg/l in T_3. In this study area the mean values of ammonia were found T_1, T_2 and T_3 0.29±0.01 mg/l, 0.32±0.01 mg/l and 0.28±0.02 mg/l respectively. The mean values of alkalinity of this area were 164.89±8.69 mg/l, 158.81±1.61 mg/l and 178.29±2.56 mg/l in T_1, T_2 and T_3 respectively.

At the Bogra Sadar Upazila the mean values of pH were found in 6.78±1.33, 7.5±0.15 and 7.82±0.10 T_1, T_2 and T_3 respectively. The mean values of dissolved oxygen in treatment T_1, T_2 and T_3 were 6.50±0.43mg/l, 5.31±1.81 mg/l and 7.30±0.25 mg/l respectively. In this study area the mean values of carbon di-oxide were 1.06±0.24 mg/l in T_1, 2.81±0.14 mg/l T_2 and 2.19±0.14 mg/l in T_3. The mean values of nitrate content in T_1, T_2 and T_3 were 0.71±0.32 mg/l, 0.66±0.29 mg/l and 0.68±0.24 mg/l respectively in Bogra Sadar Upazila. The mean values of phosphate-phosphorus were found were 1.28±0.10 mg/l, 0.85±0.22 mg/l and 0.71±0.19 mg/l T_1, T_2 and T_3 respectively. The mean values of ammonia in treatment T_1, T_2 and T_3 were 0.38±0.14 mg/l, 0.34±0.07 mg/l and 0.23±0.12 mg/l respectively. In this study area the mean values of alkalinity content of the water in treatment T_1, T_2 and T_3 were 171.88±10.51 mg/l, 188.13±17.17 mg/l and 160.31±8.53 mg/l respectively.

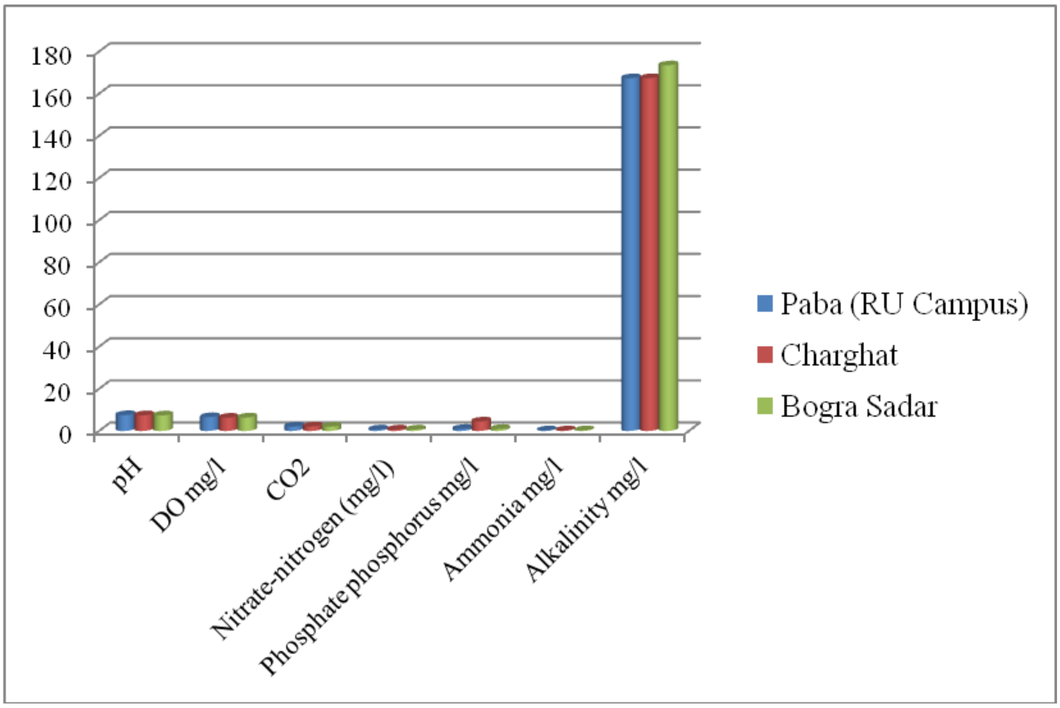


Fig 4.4: Variations of chemical parameters in three study areas at 2017

4.3.3 Biological parameters of three study areas at 2017

Plankton populations in the three study areas were identified up to genus level. Both phytoplankton and zooplankton were identified. In the Paba Upazilla (RU Campus) and in the Charghat Upazila phytoplankton population with 13 genera comprised of 4 major groups; viz., Bacillariophyceae (3 genera), Chlorophyceae (6 genera), Cyanophyceae (2 genera) and Euglenophyceae (1 genera), Chlorococcales (1 genera) were identified in the experimental ponds under different treatments during the experimental period. In these two study areas only two groups of zooplankton were identified which was composed of Crustacea (4 genera) and Rotifeia (1 genera). Among the zooplankton, Rotifera was the most dominant group over other group. But in Bogra sadar Upazila phytoplankton population with 20 genera comprised of four major groups; viz., Bacillariophyceae (4 genera), Chlorophyceae (11 genera), Cyanophyceae (3 genera) and Euglenophyceae (1 genera), Chlorococcales (1 genera) were identified in the experimental ponds under different treatrnents during the experimental period. Here 10 genera of three groups of zooplankton were identified, which was composed of Rotifera (4 genera) and Copepoda (3 genera) and Cladocera (3). Among the zooplankton, Rotifera was the most dominant over other groups. Details results are shown in table 4.42.

Table 4.42: List of plankton of study areas at 2017

Plankton	Study area		
	Paba	**Charghat**	**Bogra**
Phytoplankton	*Clostridium sp.* *Navicula sp.* *Phacus sp.* *Bacillariophyceae sp.* *Anabaena sp.* *Chlorella sp.* *Volvox sp.* *Microcystis sp.* *Aphanocapsa sp.* *Oocystis sp.* *Ulothrix sp.* *Cyclotella sp*	*Clostridium sp.* *Navicula sp.* *Phacus sp.* *Bacillariophyceae sp.* *Anabaena sp.* *Chlorella sp.* *Volvox sp.* *Microcystis sp.* *Aphanocapsa sp.* *Oocystis sp.* *Ulothrix sp.* *Cyclotella sp*	*Clostridium sp.* *Oocystis sp.* *Phacus sp.* *Navicula sp.* *Bacillariophyceae sp.* *Anabaena sp.* *Chlorella sp.* *Closterium sp.* *Cosmarium sp.* *Volvox sp.* *Spirogyra sp* *Chlorosarcina sp* *Cyclotella sp.* *Aphanocapsa sp* *Clostridium sp.* *Ulothrix sp.* *Pediastrum sp.* *Pinnularia sp.* *Nostoc sp.*
Zooplankton	*Moina sp.* *Daphnia sp.* *Cyclops sp.* *Bosmina sp.* *Ceriodaphnia sp.* *Rotaria sp.*	*Moina sp.* *Daphnia sp.* *Cyclops sp.* *Bosmina sp.* *Ceriodaphnia sp.* *Rotaria sp.*	*Moina sp.* *Daphnia sp.* *Cyclops sp.* *Bosmina sp.* *Ceriodaphnia sp.* *Rotaria sp.* *Brachionus sp.* *Keratella sp.* *Notholca sp.* *Asplanchna sp* *Diaptomus sp.* *Mesocyclops sp.* *Diaphanosoma sp.*

4.3.4 Physical parameters of three study areas at 2018

Mean values of water temperature in T_1,T_2 and T_3 of Paba Upazila (RU campus) were 27.08±0.75 ^{0}C, 26.12±0.26 ^{0}C and 25.45±0.37 ^{0}C respectively. Maximum temperature was recorded in the month of August and minimum was in December. The mean values of transparency of Paba Upazila (RU campus) were 29.01±0.11 cm, 28.80±1.02 cm and 28.77±1.11 cm in T_1,T_2 and T_3 respectively.

The mean values of water temperature in treatments T_1,T_2 and T_3 were 25.28±0.53, 26.66±0.19 and 26.92±0.12°C respectively in Charghat upazila. Maximum temperature was recorded in the month of September and minimum was in December. The mean values of transparency content of the water in treatment T_1, T_2 and T_3 were 26.50±1.35, 26.10±1.15 and 25.46±0.38 cm, respectively.

The mean values of water temperature in treatments T_1, T_2 and T_3 were 27.12±0.95°C, 26.75±0.52°C and 26.60±0.70°C of Bogra Sadar upazila. Maximum temperature was recorded in the month of August and minimum was in January. The mean values of transparency of the water 23.62±0.64cm in T_1, 24.29±1.31 cm T_2 and 24.29±0.16 cm inT_3.

Variation between temperature and transparency of three study area are presented in the figure 10 below:

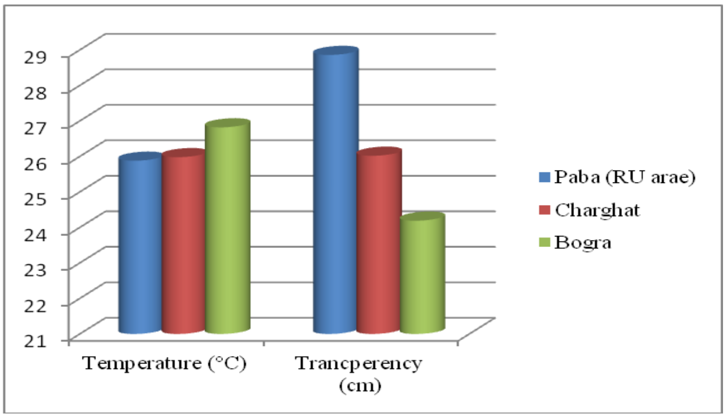


Fig 4.5: Variation between temperature and transparency of three study area at 2018

4.3.5 Chemical parameters of three study areas at 2018

From the experiment got the mean water quality parameters were in suitable range where there was no significant ($p>0.05$) difference found in temperature, transparency, pH, DO and CO_2 among the treatments.

Table 4.43: Mean values (±SD) of water quality parameters of experimental ponds on 2018 at Charghat Upazila

Study Area	Treatments	Parameters				
		pH	DO (mg/l)	CO_2 (mg/l)	Alkalinity (mg/l)	Ammonia (mg/l)
RU Area	T_1	7.40±0.24[a]	6.51±0.25[a]	3.74±0.25[a]	172.96±4.43[a]	0.23±0.03[a]
	T_2	7.41±0.47[a]	6.42±0.65[a]	3.61±0.44[a]	174.80±6.77[a]	0.24±0.03[a]
	T_3	7.34±0.72[a]	6.47±0.45[a]	4.30±0.42[a]	168.88±5.34[a]	0.18±0.03[a]
Char ghat	T_1	6.20±0.36[a]	5.43±0.68[a]	2.43±0.30[a]	170.22±3.12[a]	0.21±0.01[a]
	T_2	6.84±0.40[a]	6.80±0.88[a]	2.00±0.30[a]	165.17±5.44[a]	0.25±0.01[a]
	T_3	6.60±0.70[a]	6.43±0.86[a]	2.66±0.70[a]	169.45±3.27[a]	0.17±0.02[a]
Bogra Sadar Upazila	T_1	5.83±0.64[a]	6.20±0.45[a]	2.20±0.36[a]	167.18±5.28[a]	0.25±0.06[a]
	T_2	6.33±0.60[a]	6.10±0.90[a]	2.21±0.75[a]	173.05±4.44[a]	0.25±0.03[a]
	T_3	5.98±0.63[a]	5.93±0.15[a]	2.41±0.50[a]	164.88±6.14[a]	0.19±0.01[a]

Values in the same row having different superscript letters are significantly different ($p < 0.05$)

4.3.6 Biological parameters of three study areas at 2018

As a daily routine both phytoplankton and zooplankton were identified. In the Paba Upazilla (RU Campus) and in the Charghat Upazila phytoplankton population with 13 genera comprised of 4 major groups; viz., Bacillariophyceae (3 genera), Chlorophyceae (6 genera), Cyanophyceae (2 genera) and Euglenophyceae (1 genera), Chlorococcales (1 genera) were identified in the experimental ponds under different treatrnents during the experimental period. In these two study areas only two groups of zooplankton were identified which was composed of Crustacea (4 genera) and Rotifeia (1 genera). Among the zooplankton, Rotifera was the most dominant group over other group. But in Bogra sadar Upazila phytoplankton population with 20 genera comprised of four major groups; viz., Bacillariophyceae (4 genera), Chlorophyceae (11 genera), Cyanophyceae (3 genera) and Euglenophyceae (1 genera), Chlorococcales (1 genera) were identified in the experimental ponds under different treatrnents during the experimental period. Here 10 genera of three groups of zooplankton were identified, which was composed of Rotifera (4 genera) and Copepoda (3 genera) and Cladocera (3). Among the zooplankton, Rotifera was the most dominant over other groups. Details results are shown in table 4.44.

Table 4.44: Plankton community found in the three study areas during 2018

Plankton	Study area		
	Paba	**Charghat**	**Bogra**
Phytoplankton	*Clostridium sp.* *Navicula sp.* *Phacus sp.* *Bacillariophyceae sp.* *Anabaena sp.* *Chlorella sp.* *Volvox sp.* *Microcystis sp.* *Aphanocapsa sp.* *Oocystis sp.* *Ulothrix sp.* *Cyclotella sp*	*Clostridium sp.* *Navicula sp.* *Phacus sp.* *Bacillariophyceae sp.* *Anabaena sp.* *Chlorella sp.* *Volvox sp.* *Microcystis sp.* *Aphanocapsa sp.* *Oocystis sp.* *Ulothrix sp.* *Cyclotella sp*	*Clostridium sp.* *Oocystis sp.* *Phacus sp.* *Navicula sp.* *Bacillariophyceae sp.* *Anabaena sp.* *Chlorella sp.* *Closterium sp.* *Cosmarium sp.* *Volvox sp.* *Spirogyra sp* *Chlorosarcina sp* *Cyclotella sp.* *Aphanocapsa sp* *Clostridium sp.* *Ulothrix sp.* *Pediastrum sp.* *Pinnularia sp.* *Nostoc sp.*
Zooplankton	*Moina sp.* *Daphnia sp.* *Cyclops sp.* *Bosmina sp.* *Ceriodaphnia sp.* *Rotaria sp.*	*Moina sp.* *Daphnia sp.* *Cyclops sp.* *Bosmina sp.* *Ceriodaphnia sp.* *Rotaria sp.*	*Moina sp.* *Daphnia sp.* *Cyclops sp.* *Bosmina sp.* *Ceriodaphnia sp.* *Rotaria sp.* *Brachionus sp.* *Keratella sp.* *Notholca sp.* *Asplanchna sp* *Diaptomus sp.* *Mesocyclops sp.* *Diaphanosoma sp.*

Chapter - 5

DISCUSSION

This research work was undertaken at Paba Upazilla (Rajshahi University Campus area), Charghat upazilla and Bogura Sadar Upazilla. The main purpose of the research was to improve water retention capacity and also increase fish production, monitor water quality and growth performance. Water retention capacity and production was improved by three different techniques viz. (i) digging and polythene lining with clay soil, (ii) digging and compost layering and (iii) only digging. Water quality and growth performance was monitored fortnightly with hackit box (DR-2010, USA), net, electric balance and scale. To set up experiment a total of 27 seasonal ponds in three locations (9 at Rajshahi University campus, 9 at Charghat-Bhagha and 9 at Bogra Sadar) were selected. The selected seasonal ponds are being dug at the level of 10. Then all the prepared model ponds are being maintained 8 feet, 7 feet and 6 feet of water level for the treatmentsT_1, T_2 and T_3 respectively in each side of three upazilas. To see the water retention capacity of constructed or re-excavated model ponds, fluctuations in water depths were recorded daily. Five farmer's practiced ponds from each location were selected as control pond.

5.1: Soil conditions of Ponds

Soil condition is very much important for any type of fish culture. Fish production can be influenced by some soil characteristics. Soil texture is one of them. Water holding capacity of a pond area depends on soil texture. Intermolecular space of soil can changed it's criteria. Because with small intermolecular space of soil can hold most water and this type of soil is called clay or muddy soil. On the other hand sandy soil has lowest water holding capacity because of large intermolecular space. Soil condition differs from area to area. At first soil was tested. It is very much essential to know the soil type or soil quality before fish culture or before set up any kind of experiment. Water retention capacity of a pond mostly depends on the soil type of this pond. Soil of three upazilas was tested in two times, before and after of the pond preparation.

In Rajshahi University area the soil was sandy. The highest (40.0%) sand particle was in T_1 and lowest (28.67%) clay particle was in the T_1. During pond preparation clay soil was applied and clay particle was increased about 47.33% in T_2. This can improve the water retention capacity round the year. Lowest (24%) sand particle was in the T_2

5.2 Water Depth

In Paba upazila maximum mean water depth was found in T_1 (7.21±0.32 feet) in the month of August among the treatment. Maximum water depth was observed in the month of august due to rainy season. Water depth of the bottom layer digging model ponds of Charghat upazila was above 3 feet round the year. In Bogra Sadar upazila maximum mean water depth was found in 7.70±0.23 feet, 6.62±0.12 feet and 5.37±0.32 feet for T_1, T_2 and T_3 respectively in the month of August. In the second year experiment the highest mean water depth value in T1 was 5.81±0.51 feet in the month of January and the lowest was 4.99±0.07 in the month of July. At the Charghat Upazilla the average of water depth in treatments T_1, T_2 and T_3 were 4.65±1.14, 4.30±1.01 and 4.05±1.17 feet respectively. The maximum water depth 6.21±0.594.65±1.14 feet were recorded in treatment T_1, whereas the minimum 4.48±0.35 feet were in T_3 at the Bogura Sadar Upazilla. Depth of water has big enough effects on the productivity of a water body. According to El-Sayd *et al.* (1996) declared that growth performance and survival rate of fishes were mostly depended on depth of pond and temperature of water. In aquaculture pond depth must be deep enough to fulfill temperature demands and other habitat essentials of cultured species mostly in dry and drought prone areas. For the tropical and subtropical regions 1 meter pond depth is suitable for carp culture (Pillay 1990). Fish farmers of China used 1.5 meter pond depth is used for spawning tilapias and 2-2.5 m depth is recommended for their rearing and wintering (Lin 1991). Jhingran (1975) revealed that 2 m pond depth is suitable for the productivity of biological factors. It was found from Rahman *et al.* (1992) observation that pond should be deep for 1 meter to 5 meter and the slandered depth should be 2 meter. Hossain *et al.* (2014) reported that the mean values of water depth of fish culture ponds were different in different season. It was 0.90±0.03 meter and 0.88±0.02 meter in winter and summer respectively. Sarker and Ali (2016) stated that the average pond depth in the study area was found 2.6 meter. Islam and Chowdhury (2013) observed that the average depth of fish culture pond water was 60-320 cm or 0.6-3.2 meter (yearly mean value 158.8± 94.6 cm or 1.59± 0.95 meter).

5.3 Growth Performance

5.3.1 Weight gain (g)

H. molitrix, *L. rohita* and *C. cirrhosus* had the highest weight gain in T_1 but *B. gonionotus* and *O. niloticus* had the highest weight gain in T_3 in Rajshahi University area (Paba Upazila). Mean weight gain (g) were 355.57± 80.24[a], 196.78± 88.12[a], 198.57± 44.21[a], 232.54± 08.32[a] and 446.22± 43.92[a] of *H. molitrix*, *L. rohita*, *C. cirrhosus*, *B. gonionotus* and *O. niloticus* respectively in Paba upazila. In Charghat upazila all species except *L. rohita* had the highest weight gain (g) in T_2 and *L. rohita* had the highest weight gain in T_3. Mean weight gain of *H. molitrix* was 365.08± 08.14[a], 195.74± 28.18[a] of *L. rohita*, 241.28± 82.11[a] of *C. cirrhosus*, 314.76± 36.45[a] of *B. gonionotus* and 430.98± 09.42[a] of *O. niloticus*. In Bogra Sadar Upazila *H. molitrix* and *L. rohita* had the highest mean weight gain (g) in T_3. But *C. cirrhosus* had the highest mean weight gain (g) in T_1. *B. gonionotus* and *O. niloticus* had the highest mean weight gain (g) in T_2. Mean weight gain (g) were 291.96± 60.14[a], 131.30± 11.72[a], 137.89± 13.21[a], 210.81± 45.02[a] and 389.68± 13.42[a] of *H. molitrix*, *L. rohita*, *C. cirrhosus*, *B. gonionotus* and *O. niloticus* respectively in Bogra Sadar upazila.

Species type, availability of food according to choice and feeding frequency and the interactions among species may cause weight variation of the harvested fishes (Habib *et al.* 2003). In the present study the mean initial weight of *H. molitrix* was 58.66±0.034, 58.67±0.017 and 58.25±0.375 gm, *L. rohita* was 51.77±0.010, 51.77±0.005 and 51.77±0.011 gm, *C. cirrhosus* was 56.45±0.00,5 56.46±0.001 and 56.45±0.005 gm, *B. gonionotus* was 8.16±0.288, 8.13±0.057 and 8.30±0.264 gm and *O. niloticus* was 7.27±0.144, 7.36±0.123 and 7.37±0.075 gm for T_1, T_2 and T_3 respectively during the releasing period and the mean final weight of *H. molitrix* was 454.59±84, 416.44±15.95, and 408.44±27.50 gm, *L. rohita* was 302.61±15.85, 301.41±11.34 and 294.79±21.31 gm, *C. cirrhosus* was 293.83±10.35, 292.43±10.85 and 302.28±35.15 gm, *B. gonionotus* was 401.97±52.62 , 415.67±29.35 and 380.86±65.73 gm and *O. niloticus* was 394.76±5.27, 395.80±5.59, and 372.80±12.81gm for T_1, T_2 and T_3 respectively. The mean weight gain of *H. molitrix*, *L. rohita*, *C. cirrhosus*, *B. gonionotus* and *O. niloticus* were 395.93±84.83, 250.84±15.86, 237.37±10.35, 393.79±52.61 and 387.49±5.26 gm in T_1, 357.77±15.95, 249.64±11.33, 235.97±10.85, 407.51±29.30 and 388.43±5.72 gm in T_2 and 350.18±27.44, 243.01, 245.82±35.16, 372.55±65.51and 365.42±12.87gm in T_3

respectively. There was significant ($p<0.05$) difference among the treatments in case of weight gain of *O. niloticus* but there was no significant ($p>0.05$) difference among the treatments in case of *H. molitrix, L. rohita, C. cirrhosus* and *B. gonionotus*. Basak *et al.* (2017) found that the weight gained by rui and mrigal was, (572.40±153.90 g) and (532.0±117.54 g) in treatments T_3. The mean final weight of H. molitrix, C. carpio and *C. idella* varied between 580 – 598 g, 540 – 567 g and 516 – 542.5 g respectively in a carp polyculture pond (Hossain *et al.* 2008). Ahmed 1993 found the growth rates of rohu varied from 248.20 to 736.90 g/10 months. In different research different results were found. Hossain et al. 1994, Rahman et al 1995, Miah et al. 1997, Ahmed and Alam (1989) worked on growth performance of fishes. Ahmed (1993) found the growth rate of mrigala varies from 430 to 741 g in one year and Mazid *et al.* (1997) found 460g to 860g weight gains in 10 months culture period. The mean weight gain of native major carps was 469.03 g (*L. rohita*), 347.9 g (*C. catla*) and 321.67 g (*C. mrigala*) in polyculture where the initial mean weight was 291.07, 230 and 198 g respectively (Mamun and Mahmud 2014). Sarkar *et al.* (2014) found in his research the highest mean final weight gain (g) of silver carp; tilapia, rui and mrigal were 258.8, 154.8, 119.7 and 124.7 respectively in one of three treatments (T_3).

5.3.2 Specific growth rate (bwd^{-1})

In Paba Upazila specific growth rate (SGR) of fish species in various treatments ranged from 2.22% to 2.32%.The specific growth rate of fish species 2.23%, 2.27% and 2.22% in T_1, T_2 and T_3 respectively. The highest specific growth rate was obtained 2.32% in T_1. The lowest specific growth rate 2.22% observed in T_3. There was significant ($p<0.05$) difference among the treatments. Specific growth rate of fish species of Charghat Upazila in different treatments ranged between 1.25% to 1.33%.The specific growth rate of fish species 1.25%, 1.33% and 1.33% in T_1, T_2 and T_3 respectively. The highest specific growth rate was obtained 1.33% in T_3. The lowest specific growth rate 1.25% observed in T_1. There was significant ($p<0.05$) difference among the treatments. In Bogra Sadar Upazila specific growth rate of fish species in different treatments were very nearer. It was ranged between 2.21% to 2.22%.The specific growth rate of fish species 2.21% in T_1, 2.22% T_2 and T_3. There was significant ($p<0.05$) difference among the treatments.

Similar result was revealed by Hossain *et al.* (1997) during polyculture of fishes in seasonal ponds by fertilization and feeding. He also worked by only fertilization and only feeding. But by using both fertilization and feeding found the best results. Kohinoor *et al.* (1994) found the Specific growth rate of Thai sharpunti ranged between 1.33 to 1.35% in polyculture with carps using low-cost feed. In the present study higher numbers of fishes were stocked and it may be the reason of the data were higher than those from the review data. Hossain *et al.* (2013) reported SGR of Silver carp fry ranges from 1.91±0.40 to 1.55±0.43% at stocking density of 1,23,500/ ha. Priyadarshini *et al.* (2011) got the SGR of *Cyprinus carpio* fry 3.47 %. Hossain and Islam (2006) found the SGR of prawn, catla, rohu and silver carp ranged from 3.99 to 4.26%, 3.71% to 3.83%, 2.49 to 2.55% and 2.44% to 2.59% respectively. Desilva and Davy (1992) concluded that SGR of fishes which fed on high protein and energy diet shows higher value but fish fed only supplement feeds made on farm shows SGR value between 3-4% per day.

5.3.3 Food conversion ratio (FCR)

In three study areas food conversion ratio (FCR) of the diet used for feeding fry, at the rate of two times in a day were found as 0.18, 0.23 and 0.17 in T_1, T_2 and T_3 respectively of Paba, 0.40, 0.40 and 0.27 in T_1, T_2 and T_3, respectively of Charghat and 0.24, 0.38 and 0.17 in T_1, T_2 and T_3 respectively in Bogra upazila. The mean least FCR value 0.17 was found in Paba and also Bogra. On the other hand the highest mean FCR value 0.40 was found in Charghat where fry fed two times daily. There was significant ($p<0.05$) difference among the treatments. Duston et al. (2004) who recorded food conversion ratio (FCR) values to range from 1.03 to 1.20 on tilapia culture.

5.3.4 Production

The average net production of model ponds was 16.11, 17.27 and 13.78 kg/decimal for Paba, Charghat and Bogura Sadar Upazila respective and in second experiment it was 17.58, 15.21 and 14.27 kg for Paba, Charghat and Bogura Upazila respectively. The yearly fish production was found to be ranged as 3119 to 4067 kg/ha/year in the traditional carp polyculture system in Bangladesh (Hossain et al. 1997; Mazid et al. 1997). Yearly fish yield of 3400-6800 kg/ ha has been observed from the earthen polyculture ponds of north-east Indian region (Shing et al. 2013).The yield of carp polyculture was found as 5361.5-11321.7 kg/ ha/1yr (Hosen et al. 2014). Total yield (3675.33 kg /ha/6month) was reported in carp polyculture pond by Asadujjaman and Hossain (2016). Haque et al. (2015), obtained the highest production in treatment T2 (2747.47±116.47 kg/ha/ year) followed by T3 (2622.04±327.67 kg/ha/year) and T1 (2618.85±575 kg/ha/year) where the stocking density of 80 fingerlings per decimal was the most suitable to ensure highest production in polyculture. Mohsin et al. (2013) found that for some problems, the farmers cannot use inputs and experiences satisfactorily so that fish production (3598.72±785.83 kg/ha/yr) to the carp farmers in Rajshahi and Natore region of northern side of Bangladesh is not satisfactory. Hosen et. al. (2014) calculated that gross and net yields of fish were 16.56 ton/ ha (15,022.98 kg/ha) and 12.48 ton/ ha (11,321.67) respectively in case of fertilization and artificial feeding application (T_1) and 9.99 ton /ha (9,062.78 kg/ ha) and 5.91 ton /ha (5,361.46 kg/ha) respectively in case of only fertilization (T_2) in polyculture of *Cirrhinus mrigala*, *Hypophthalmicthys molitrix* and *Oreochromis niloticus*. Rahman and Rahman (1999) obtained the average yield/ha/yr was 7.903 m.ton (7,903 kg/ha/yr) in case of fertilization and artificial feeding application and 3.374 m.ton (3,374 kg/ha/yr) in case of only fertilization application from polyculture of Indian and Chinese major carps and catfishes. Fish production obtained in three treatments was 2325±74.75, 2620±49.66 and 2982±171.52 kg/ha in the study conducted by Alam et al. (2002). Hossain et. al., (1997) got the best production (2450 Kg/ha) in the polyculture of fishes in seasonal ponds through fertilization and feeding. Rahman et. al. (2017) showed the total yield of all species of fish was 2360 kg/ha/6 months under treatment-1 (T_1), whereas the total yield of fish was 4022.5 kg/ha/6 months under treatment-2 (T_2) in case of carp polyculture. Murty et al. (1978) found gross and net fish productions with supplementary feed was 4096.09 and 3858 kg/ha/yr and without supplementary feed was 2512.67 and 2275.37 kg/ha/yr. Gupta et al. (1990) reported 4917 kg/ha/yr with supplementary feed and 2583 kg/ha/yr productions and without supplementary feed. Rahman (1997) also obtained 7903 kg/ha/yr with supplementary feed and 3374 kg/ha/yr without supplementary feed. In aquaculture through polyculture system, the gross production was recorded 1,817 kg/ha by Kohinoor (2000) and 1,970 kg/h by Kadir et al. (2006) at five months of culture period. The carp production (Mixed culture of Indian and Chinese carp) in fresh water ponds in India was 3314-4000

Kg/ha/yr with supplementary feed inputs and 4244-5506 Kg/ha/yr with both fertilizer and supplementary feed inputs reported by Sinha (1979). Sagor (2008) found the average production of carp 1676 kg/ha/year. Haque (2010) observed better results from the polyculture of Indian carps in three treatments and the production ranging from 2618.85±57.5 to 2747.47±116.47 kg/ha/year. Methew et al. (1988) observed the production of 10183 kg/ ha/ yr when stocking density was 8,000 fish/ha in six carp fish species at polyculture. Das et al. (1999) also obtained the production of 5,556 kg/ha/yr from the Indian major carp at the stocking density of 7,000 fish/ha. Uddin et al. (1994) got the gross production of 3,415 kg/ ha/ yr from polyculture of carps with rajpunti. Miaje (1999) reported the total production of fish ranged between 2,934 and 3,318 kg/ha/4 months in polyculture of Indian major carps with Thai sharpunti by feeding with 20.31% protein rich diet. Ferdosh (2003) recorded a total production ranging from 1908.2 to 2082.68 kg/ha/142 days in carp-sis polyculture system. Jhingran (1975) and Chaudhuri (1978) also reported good results from the polyculture of Indian major carps with exotic species and the yield recorded by them 7000-9000 kg/ha/yr and 7444.8 kg/ha/yr respectively. Wahab et al. (1995) also recorded 5,294 to 5,630 kg/ha/yr production in the polyculture of carps. Lakshmanan et al. (1971) declaired a production ranging from 2230 to 4209 Kg/ha/yr in a 7 species mix culture of Indian and Chinese carps with the use of fertilization and supplementary feed. The range of production from the traditional polyculture of carps in Bangladesh was 3,119 to 4,067kg/ha/yr found from different researcher like Dewan et al. (1988), Ameen et al. (1983), Uddin et al. (1994), Miah et al. (1993), Hossain et al. (1994), Miah et al. (1997) and Mazid et al. (1997) etc..

5.4 Water Quality Parameter

Regular monitoring of water quality is very important for fish culture. Parameters should be in suitable range to get much production. Physical, chemical and biological parameters were monitored in three study areas.

5.4.1 Physical parameters

Average of water temperature in T_1,T_2 and T_3 of Paba Upazila (RU campus) were 27.69±3.91^{0}C, 28.06±3.91^{0}C and 28.44±3.88^{0}C respectively. Maximum temperature was recorded in the month of August and minimum was in December. The mean values of transparency of Paba Upazila (RU campus) were 25.63±0.33 cm, 27.50±0.83 cm and 27.69±1.66 cm in T_1, T_2 and T_3 respectively. The mean values of water temperature in treatments T_1, T_2 and T_3 were 29.21±0.83, 28.69±0.69 and 29.42±0.92°C respectively in Charghat upazila. Maximum temperature was recorded in the month of September and minimum was in December. The mean values of transparency content of the water in treatment T_1, T_2 and T_3 were 25.98±0.48, 25.97±0.46 and 27.85±0.86 cm, respectively. The mean values of water temperature in treatments T_1, T_2 and T_3 were 26.69±1.90°C, 27.06±1.80 °C and 29.44±2.21 °C of Bogra Sadar upazila. Maximum temperature was recorded in the month of August and minimum was in January. The mean values of transparency of the water 22.63±0.21cm in T_1, 24.50±1.02 cm T_2 and 20.60±1.60 cm inT_3. Temperature both air and water is very important for pond environment and an important physical factor in controlling the functioning of aquatic ecosystem. (Wetzel, 1975; Dwivedi and Pandey, 2002; Singh and Mathura, 2005). Water temperature is one of the most important physical factors for all aquatic life. All biological and chemical processes in an aquaculture system are influenced by temperature. At water or air temperatures above or below the optimum limit, fish growth is reduced and mortality rate became high (Joseph *et al.*, 1993). Boyd (1982) said that the water temperature from 26.06 to 31.97ºC is suitable for warm water fish culture. From the findings it was shown that a temperature range between 25 and 32ºC is ideal for tropical fish culture (Bolorunduro and Abdullah, 1996). Islam and Chowdhury (2013) recorded water temperature which varied from 20-32.5º C (yearly mean value 28.29±4.96º C). Rumpa *et al.* (2016) observed during the study time that the ranges of water temperature was 26 to 34℃. Wahab *et al.* (1995) stated that, the temperature range suitable for plankton growth is 27.2 C to 32.4 C. Temperature values in the ponds in the study area ranged from 26.8 to 29.6°C. Choudary *et al*., (2014) study the ponds of Sasaram, Bihar observed the temperature range varies from 23^{o}C to 27^{o}C. Sajitha and Vijayamma (2016) observed the temperature values in the ponds in the study area ranged from 26.8 to 29.6°C.Mollah and Haque (1978) recorded the water temperature ranges from 26.0 to 32.44°C. For freshwater aquaculture the suitable range of temperature is about 25-32ºC (Das, 1997). Ghosh B. B. (2018) Water temperature was found to be highest in June (31.8°C) and lowest in January (16°C). Alam *et al.* (2002) studied the carp polyculture in pond and reported water temperature 31.85°C. Water temperature from 27.1 – 28.7 °C was also reported in polyculture pond by Ahmad et *al.* 2013.Kohinoor et al. 2011 observed temperature ranged from 26.40±0.42°C to 26.72±0.50°C Khan *et al.* (2018) reported that the mean values of water temperature varied from 26.58 ± 0.97 – 26.75 ± 1.08°C. Hossain *et al*. (2008) also reported water quality parameters in polyculture ponds at which the water temperature ranged from 25.6 – 25.8 °C. Water temperature was recorded as 30.80±1.52 and 31.28±1.47°C by Hosen *et al.* 2014. The mean value of water temperature 28.93 ± 2.53°C was reported by Rahman and Rahman (1999). Water temperature throughout the experiments by Ghozlan *et al.* (2018) ranged between 24.13±0.53 and 30.26±0.45 °C in fresh water experiment. Munni *et al.* (2013) investigated water temperature 29-38.3°C. Uddin, M. A. (2002) in his study observed that temperature varied from 25.6 to 33.0°C. Rahman, M. M. (2000) studied the water quality of freshwater fish pond and reported that temperature varied from 21.1 to 32.2°C.

Boyd (1982) recommended a transparency range between 15 to 40 cm appropriate for fish culture. Kohinoor *et al.* 2011 observed the mean value of water transparency was 32.22±1.40, 36.40±1.66 and 40.55±1.69 cm. Haque *et. al* (2015) recorded he mean values of water transparency varied from 30.69±1.07 to 34.11±0.97 cm. Hosen *et. al*. 2014 reported transparency was 24.54±6.94 33.25±5.98 cm in his study. Rumpa *et al.* (2016) observed transparency (28 to 41 cm). Munni *et al.* (2013) found transparency 32.5-57.5 cm. Uddin, M. A. (2002) in his study observed transparency from 11.0 to 63.5 cm .Transparency was recorded from 18.2-25.5 cm by Ahmad et *al.* 2013. Hossain et al. (2008) recorded the transparency which varied from 28.5-29.7 cm. Alam *et al.* (2002) observed the mean value of transparency as 30.11 cm. Khan *et al.* (2018) reported that the mean values of transparency varied from 35 ± 0.83 – 37.17 ± 0.86 cm. Rahman, M. M. (2000) reported that transparency varied from 12 to 41 cm. Sarker, M. N. (2000) observed transparency from 27 to 35 cm. Roy et. al. (2001) measured transparency from 24.10 cm to 45.00 cm. Kohinoor (2000) recorded that transparency ranged from 15cm to 58 cm.

5.4.2 Chemical parameters

At Paba Upazila (RU Campus) the mean values of pH content of the water in T_1, T_2 and T_3 were 7.38±0.18, 7.47±0.15 and 7.72±0.34 respectively. The mean values of dissolved oxygen of this area were 6.00±0.5 mg/l, 6.31±0.86 mg/l and 7.38±0.65 mg/l in T_1, T_2 and T_3 respectively. The mean values of carbon di-oxide content of the water were 2.06±0.32 mg/l in T_1, 1.81±0.39 mg/l in T_2 and 2.29±0.13 mg/l T_3. The mean values of nitrate content of the water in treatment T_1, T_2 and T_3 were 0.77±0.31 mg/l, 0.62±0.30 mg/l and 0.69±0.21 mg/l respectively in Paba Upazila (RU Campus). The mean values of phosphate-phosphorus were 1.30±0.10 mg/l in T1, 0.95±0.20 mg/l T_2 and 0.63±0.18 mg/l in T_3. In this study area the mean values of ammonia were found T_1, T_2 and T_3 0.35±0.07 mg/l, 0.32±0.05 mg/l and 0.21±0.05 mg/l respectively. The mean values of alkalinity of this area were 164.89±8.69 mg/l, 158.81±1.61 mg/l and 178.29±2.56 mg/l in T_1, T_2 and T_3 respectively. The mean values of pH content of the water in T_1, T_2 and T_3 were 7.35±0.10, 7.44±0.09 and 7.55±.13, respectively in Charghat Upazila. The mean values of dissolved oxygen of this area were 6.12±0.13 mg/l, 6.36±0.15 mg/l and 6.37±0.05 mg/l in T_1, T_2 and T_3 respectively. The mean values of carbon di-oxide content of the water were 2.18±0.17 mg/l in T_1, 1.84±0.11 mg/l in T_2 and 2.33±0.08 mg/l T_3. The mean values of nitrate content of the water in treatment T_1, T_2 and T_3 were 0.83±0.02, 0.58±0.02 and 0.72±0.02 mg/l respectively in Charghat Upazila. The mean values of phosphate-phosphorus were 4.60±0.10 mg/l in T_1, 4.47±0.17 mg/l in T_2 and 4.42±0.06 mg/l in T_3. In this study area the mean values of ammonia were found T_1, T_2 and T_3 0.29±0.01 mg/l, 0.32±0.01 mg/l and 0.28±0.02 mg/l respectively. The mean values of alkalinity of this area were 164.89±8.69 mg/l, 158.81±1.61 mg/l and 178.29±2.56 mg/l in T_1, T_2 and T_3 respectively.

At the Bogra Sadar Upazila the mean values of pH were found in 6.78±1.33, 7.5±0.15 and 7.82±0.10 T_1, T_2 and T_3 respectively. The mean values of dissolved oxygen in treatment T_1, T_2 and T_3 were 6.50±0.43mg/l, 5.31±1.81 mg/l and 7.30±0.25 mg/l respectively. In this study area the mean values of carbon di-oxide were 1.06±0.24 mg/l in T_1, 2.81±0.14 mg/l T_2 and 2.19±0.14 mg/l in T_3. The mean values of nitrate content in T_1, T_2 and T_3 were 0.71±0.32 mg/l, 0.66±0.29 mg/l and 0.68±0.24 mg/l respectively in Bogra Sadar Upazila. The mean values of phosphate-phosphorus were found were 1.28±0.10 mg/l, 0.85±0.22 mg/l and 0.71±0.19 mg/l T_1, T_2 and T_3 respectively. The mean values of ammonia in treatment T_1, T_2 and T_3 were 0.38±0.14 mg/l, 0.34±0.07 mg/l and 0.23±0.12 mg/l respectively. In this study area the mean values of alkalinity content of the water in treatment T_1, T_2 and T_3 were 171.88±10.51 mg/l, 188.13±17.17 mg/l and 160.31±8.53 mg/l respectively.

Rahman, M. M. (2000) found pH from 6.0 to 9.1. Uddin, M. A. (2002) in his study observed water pH from 6.1 to 8.88. The mean value of pH 5.31±0.64 and 5.21±0.54 was recorded by Hosen et al. 2014. Different researchers have recorded a wide variations for pH from 7.18 to 9.24 (Kohinoor *et al*. 1998), 7.03 to 9.03 (Roy *et al*. 2002), 6.8 to 8.20 (Begum *et al.* 2003) and 7.50 to 8.20 (Chakraborty *et al.* 2005) in fertilized fish pond. The pH values of pond water were found to be fluctuated and ranged from 6.8 to 8.6 was reported by Haque *et. al* (2015). Ahmad et *al.* 2013 recorded pH from 8 to 8.2. Hossain *et al.* (2008) reported pH from 7.7 – 7.9. Alam *et al.* (2002) recorded the pH value which was 6.98. Khan *et al.* (2018) reported that the mean values of pH varied from 7.38 ± 0.11 – 7.57 ± 0.1. The water pH values throughout the experiment of Ghozlan *et al.* 2018 ranged between 8.00±0.13and 8.10±0.13 with an overall mean of 8.04±0.13 in fresh water. Sajitha and Vijayamma (2016) observed pH ranged between 4.62 to 7.21. According to Swingle (1967) and Hossain *et al.* (2006), pH 6.5 to 9.0 is suitable for pond fish culture. Rumpa *et al.* (2016) observed pH (7.0 to 8.5). Hossain *et al.* (2014) in his study found the mean values of pH 8.24±0.49. Munni *et al.* (2013) in her study found pH value 6.8- 7.12. The mean value of pH in the present study was 7.40±0.24, 7.41±0.47 and 7.34±0.72 for T_1, T_2 and T_3 respectively which were within the acceptable range required for fish culture 6.5 to 9.0 (Boyd, 1990). The pH values were also within the range found by Hossain *et al.* (2013), Hossain *et al.* (2012) and Chakraborty and Mirza (2007). In the present study the mean value of pH in T_1, T_2 and T_3 was 7.40±0.24, 7.41±0.47 and 7.34±0.72 respectively. There was no significant ($p>0.05$) difference among the treatments. The maximum mean value of pH was 7.9 in the month of January under the T_2 and the minimum pH value was recorded as 6.59 in the month of May under the T_1.Oxygen is important for direct intake of many organisms and affects the solubility of many nutrients (Wetzel, 1983). From the Jhingran (1982)'s findings we can see that the oxygen contents in tropical water would be low considering their high temperature. Ghozlan et al. 2018 observed overall mean of DO of their study was 7.20±0.37mg DO/l for fresh water experiment. Sajitha and Vijayamma (2016) observed dissolved oxygen ranged from 1.76 – 8.4 mg/l. Rumpa et al. (2016) observed dissolved oxygen (2.45 to 5.5 mg/l). Hossain et al. (2014) in his study found the mean values of dissolved oxygen 5.88±2.18 mg/l. Sarker, M. N. (2000) dissolved oxygen 3.57 mg/l to 8.84. Rahman, M. M. (2000) found dissolved oxygen 2.39 to 10.36 mg/l. Uddin, M. A. (2002) found DO from 2.2 to 8.8 mg/l. Dissolved oxygen

5.31±0.64 and 5.21±0.54 mg/L was reported by Hosen *et al*. 2014. The Dissolved Oxygen concentrations of different ponds were ranged from 3 to 14 was reported by Haque *et al.* (2015). Johnson (1986) reported that fish need about 5 mg oxygen/liter or more to avoid stressful conditions. DO was recorded from 5.2 – 5.9 mg /l by Ahmad et al. 2013. Hossain et al. (2008) observed that DO ranged from 5.3 – 5.6 mg/l. Khan et al. (2018) reported that the mean values of, DO varied from 5.3 ± 0.13 – 85.5 ± 0.46 mg /L. The mean values of DO were 5.66±0.21 mg/ L, 5.20±0.18 mg/L and 4.42±0.34 mg/L recorded by (Kohinoor et al. 1998). Munni et al. (2013) found DO 1.1-6.9 mg/l in her study. Free CO2 4.65±0.17 and 4.58±0.27mg/L was reported by Hosen et. al.2014. Khan et al. (2018) reported that the mean values of free CO2 varied from 4.92 ± 0.17 – 5.58 ± 0.12 mg /L. Rahman and Rahman 1999 recorded the mean values of free CO2 were 6.13 ± 0.89 and 5.88 ± 0.55. Generally free CO_2 in more than 20 mg/L may is harmful to fishes on the other hand low oxygen content (less than 3 to 5 mg/L) in waters is harmful for aquatic organisms (Lagler 1972). Total alkalinity levels for natural waters are suitable from less than 5 mg/L to more than 500 mg/L (Boyd 1982). But Mairs (1966) said that water bodies having total alkalinity 40 mg/L or more are suitable for production. Boyd (1982) said that the total alkalinity should be more than 20 mg/L in fertilized ponds. Alam *et al.* (2002) reported that alkalinity was 125 mg/l in their study. Khan *et al.* (2018) found total alkalinity was 99.96 ± 4.71 – 110.38 ± 6.21 mg /l. Kohinoor *et al*. 1998 found mean values of total alkalinity were 154±6.30 mg/l, 130±8.44 mg/l and 121±7.60mg/l. Roy (2002) found the average total alkalinity above 100 mg/L in his study. Total alkalinity 99.15±9.11 and 97.71±8.26 mg/L was reported by Hosen *et al*. 2014. The average mean values of alkalinity were 139.88 ± 30.80 mg/L and 97.88 ± 13.09 mg/l observed by Rahman and Rahman 1999. Rumpa *et al.* (2016) observed total alkalinity (130 to 182 mg/l). Hossain *et al.* (2014) in his study found the mean values of total alkalinity 184.72±22.72. Hossain *et al.* (2013), Hossain *et al.* (2012), reported alkalinity varied from 110±5.05 to 117±7.17 mg/l in nursery pond. Munni *et al.* (2013) found total alkalinity 43.5-62.5 mg/l. Uddin, M. A. (2002) found total alkalinity from 45 to 180 mg/l. Khan *et al.* (2018) reported ammonia-nitrogen varied from 0.04±0.002–0.05±0.008 mg /L. The water un-ionized ammonia (NH_3) throughout the experiments of Ghozlan *et al.* 2018 ranged between 0.09±0.01 and 0.12±0.01 with an overall mean of 0.11±0.01 in fresh water. Rumpa *et al.* (2016) observed ammonia nitrogen (0.12 to 0.3 mg/l). Hossain *et al.* (2014) in his study found the mean values of ammonia nitrogen 0.21±0.05. , Rahman, M. M. (2000) found total ammonia 0.03 to 2.72 mg/l. Paul, S. (1998) found ammonia nitrogen 0.01 to 0.99 (mg/l). Wahab *et al.* (1995), Kadir *et al.* (2007) and Milstein *et al.*, (2009) recorded ammonia nitrogen (NH_3-N) of 0.09 to 0.99 mg/l, 0.11 to 0.52 mg/l and 0.6 to 0.29 mg/l, respectively. In the present study the mean value of ammonia-nitrogen in T_1, T_2 and T_3 was 0.23±0.03, 0.24±0.03 and 0.18±0.03 mg/l respectively. There was no significant ($p>0.05$) difference among the treatments. The maximum mean value of ammonia-nitrogen was 0.41 mg/l in the month of May under the T_1 and the minimum value was recorded as 0.04 mg/l in the month of December under the T_1.

5.4.3 Biological parameters

Plankton populations in the three study areas were identified up to genus level. Both phytoplankton and zooplankton were identified. In the Paba Upazilla (RU Campus) and in the Charghat Upazila phytoplankton population with 13 genera comprised of 4 major groups; viz., Bacillariophyceae (3 genera), Chlorophyceae (6 genera), Cyanophyceae (2 genera) and Euglenophyceae (1 genera), Chlorococcales (1 genera) were identified in the experimental ponds under different treatrnents during the experimental period. In these two study areas only two groups of zooplankton were identified which was composed of Crustacea (4 genera) and Rotifeia (1 genera). Among the zooplankton, Rotifera was the most dominant group over other group. But in Bogra sadar Upazila phytoplankton population with 20 genera comprised of four major groups; viz., Bacillariophyceae (4 genera), Chlorophyceae (11 genera), Cyanophyceae (3 genera) and Euglenophyceae (1 genera), Chlorococcales (1 genera) were identified in the experimental ponds under different treatrnents during the experimental period. Here 10 genera of three groups of zooplankton were identified, which was composed of Rotifera (4 genera) and Copepoda (3 genera) and Cladocera (3). Among the zooplankton, Rotifera was the most dominant over other groups.

Ansari, et al, (2015) identified seventy three genera of phytoplankton, belonged to four classes viz., Euglenophyceae, Chlorphyceae, Bacillariophyceae and Cyanophyceae were identified. Asha et al, (2015) identified phytoplankton, belonging to the class Cyanophyceae, Chlorophyceae, Bacillariophyceae. Ekhala et al, (2013) identified total of forty six species of phytoplankton belonging to Euglenophycae, Chlorophyceae, Bacillariophyceae and Cyanoophyceae. Uddin, M. M. (2002) gave an accunt of 35 genega of phytoplankton belonging to Bacillariophyceae (6), Chlorophyceae (18), Cyanophyceae (8) and Euglenophyceae (3) were recorded. Raihan, A. (2001) identified 31 genera of phytoplankton belonging to Bacillariophyceae (4), Chlorophyceae (18), Cyanophyceae (6) and Euglenophyceae (3). Hoque, M. I. (2000), identified 33 genera of phytoplankton belonging to 5 different groups of Bacillariophyceae, Cyanophyceae, Euglenophyceae, and Dinophyceae. Nur, N. N, (1999) identified 33 genera of phytoplankton including Bacillariophyceae (5 genera), Chlorophyceae (19 genera), Cyanophyceae (6 genera) and Euglenphyceae (3 genera) and 11 genera of zooplankton including Crustacea (4 genera) and Rotifera (7 genera). Nirod, D. B, (1997) found that phytoplankton population was comprised of four groups; Bacillariophyceae (3 genera), Chlorophyceae (15 genera), Euglengphygeae (2 genera) and Cyanophyceae (5 genera). Wahab et al. (1995) found five major groups of phytoplankton belonging to Bacillariophyceae (7 genera), Chlorophyceae (22 genera), Cyanophuyceae (9 gemera), Euglenophyceae (3 genera), and Rhodophyceae (l genera). Dewan et al. (1991) identified 24 genera of phytoplankton belonging to Chlorophyceae (15 genera), Bacillariophyceae (3 genera), Euglenophyceae (2 genera), Rhodophyceae (1genera) and Cyanophyceae (3 genera). Banu et al. (1987) identified 27 different genera among which the dominant genera were Anabaena, Anabaenopsis, Microcystis, Chlorococcus, Pediastrum, Melosiru, Brachiunus, Keratella, Filinia, Daphnia, Diaphanosoma and Cyclops. Dewan et al. (1991) identified 7 genera of zooplankton belonging to Hydrozoa (1 genera), Rotifer (3 genera) and Crustacea (5 genera). Wahab et al. (1995) found zooplankton was comprised of only Crustacea and Rotifera. Nirod, D. B, (1997) found two groups of zooplankton belonged to Crustacea (5 genera), and Rotifera (7 genera).Nur, N. N, (1999) identified 11 genera of zooplankton including Crustacea (4 genera) and Rotifera (7 genera). Hoque, M. I. (2000), identified 13 genera of zooplankton belonging to 4 groups of Cladocera, Copepoda, Rotifera and nauplius. Asha et al, (2015) zooplanktons found were Zoea larvae and Mysis larvae of prawn.

Chapter - 6

CONCLUSION AND RECOMMENDATIONS

The main purpose of the research was to improve water retention capacity as well as increase fish production. Water retention capacity and production was improved by three different techniques viz. (i) digging and polythene lining with clay soil, (ii) digging and compost layering and (iii) only digging. 27 prepared model ponds were being dug at the level of 10 feet and the water level was maintained to 8, 7 and 6 feet for T_1, T_2 and T_3 respectively. 80 fingerlings/decimal for the first year experiment and 61 fingerlings/decimal for second year experiment stocking models were released for each model ponds in three study areas. Commercial fish feed of 4%total biomass was used twice daily, water depth was recorded daily and water quality was monitored fortnightly. Soil condition were tested and maximum ponds were sandy loamy in nature. After intervention of three systems the water holding capacity of seasonal ponds were increased in all the three techniques. Thus the seasonal ponds were converted into perennial ponds to seasonal ponds comparing with 5 controlled ponds. The fish culture period of model ponds at three sites were recorded almost double against the 5 controlled ponds. Water retention capacity of the ponds was increased by the enhancing the culture period. Culture period was increased 8 months to 3 to 4 months in the most of the study area. Production has increased almost double because of scientific culture technique and seasonal ponds converted to perennial. The average net fish production of five control ponds was 4.35 kg/decimal, 4.32 kg/decimal and 5.14 kg/decimal for Paba upazila, Charghat upazila and Bogura sadar Upazila respectively for 1st experiment whereas the second experiment the average net fish production of five control pond was 5.13 kg/decimal, 5.09 kg/decimal and 5.28 kg/decimal for Paba upazila, Charghat upazila and Bogura sadar Upazila respectively. The average net production of model ponds was 16.11, 17.27 and 13.78 kg/decimal for Paba, Charghat and Bogura Sadar Upazila respectively and in second experiment it was 17.58, 15.21 and 14.27 kg for Paba, Charghat and Bogura Upazila respectively. So above results are showing that the average net production was more than 3 times better in model ponds than the controlled ponds. Maximum net production was found in Paba upazila due to increase water holding capacity of ponds and scientific fish culture techniques. Farmers have been benefited more than past and the social acceptance of the research findings have been increased by the society tremendously.

Recommendations

- In the Northwest region of Bangladesh most of the pond owners are not aware of fish culture in scientific way due to lack of water of their ponds. To increase the production of fish through culture, the techniques that have been developed for conversion of seasonal ponds to perennial ones need to be undertaken under the public extension programme for wider adoption in the north-west region.
- Awareness building on water retention and fish culture techniques should be done through farmers. Further research should be undertaken covering wider areas to improve the techniques.

Chapter - 7

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