CHAPTER 5 *DISCUSSION*

PHYSICOCHEMICAL PARAMETERS

Weather condition

The weather during the summer season (March to June) remains bright and sunny throughout the investigation. In winter season (July to October), the sunny and bright weather with clear or lightly clouded sky is observed. Heavily clouded or clouded weather with frequent rain marks the season of rain. It agrees to the findings of Cook (2009).

In the summer season the weather remains bright and sunny throughout the investigation. The high atmospheric temperature results rapid rate of evaporation and enhanced decomposition rate of organic substances. The diffusion rate of atmospheric oxygen decreases because of the high temperature of aquatic body, resulting in low content of dissolved oxygen and depletion of water (Idvis et al,2003; Odhiambo, 2013).The cloudy weather of the rainy season along with frequent rain results in depletion of photosynthesis rate of aquatic body.

The winter season with bright days and optimum weather is the most favourable season for the biological production in the aquatic body. Due to fall of temperature in winter, thus biological functions in fish are influenced. But the investigations of Hossain et al.(2014) on *Cyprinus carpio* var. *specularis*, the mirror carp in the nursery ponds of Banbelgharia, Natore district, Bangladesh reveals that rate of growth mirror carp along with other freshwater carps in cultured media decreases during the low temperature period of water. This finding contradicts the present investigation.

Water Temperature

The degree of hotness or coldness of the body of a living being either in aquatic or on terrestrial system is termed as temperature (Lucinda and Martin, 1999). In the view of Delince (1992), temperature range 30-35ºC is within the tolerance of fish (Bhatnagar and Devi, 2013).Temperature range 28-32^{o}C is good for tropical major carps, < 20^{0}C - sub lethal for growth and survival for fishes and > 35^{o}C- lethal to maximum number of fish species (Bhatnagar et al.2004). Santhosh and Singh (2007) recommend that appropriate temperature of water for carp culture is within 24^{o} and 30^{o}C (Bhatnagar and Devi, 2013).

It is noticed that the mean of temperature is recorded 30.5^{o}C the whole time of the study. The above literature studies supports that this temperature is appropriate for carp culture of carp.

Water colour

For the estimation of the condition of a water reserve for fish growth, water colour is an important parameter. The colloidal matters of humus, suspended particles and plankton growth impart variation in water colour and water quality in different month of the year as suggested by Jhingran (1991), Nair et al. (2015).

According to National Agricultural Extension and Research(1996) pale, light greenish or greenish water is most fit for fish growth as those are imparted by phytoplankton and zooplankton growth. Golden brown or reddish-brown color of water is described as average productive; light or bright green color as highly productive and dark green or blackish green color as low productive (Mane et al., 2017).

In this study the colour of the pond water, remain clear, transparent but; pale, greenish and rarely bluish-green in colour in the winter season. So, it acts as the appropriate season for pisciculture. In summer, the initial colour of water is transparent and clear, which gradually became dirty and opaque with increase turbidity in late summer due to improper uses of man and animal and fishing. This has the same openion with findings of Mane et al. (2017) that clear water is unproductive for fish/shrimp culture as it indicates very low or absence of biological production and not fertile enough and fish will not grow well in it.

During the season of rain, the water becomes muddy due to surface run-off containing minerals, humus, silts, inorganic and organic materials. It is also inadequate for pisciculture. The same opinion is provided by Helfrich and Newcomb (2009) that cloudy, muddy water is not only unpleasant, but can be harmful to aquatic life and can seriously reduce fish production due to reduced penetration of sunlight, less production of plankton, low output of DO, lowered fish food supply of fish food and visibility. The muddy rain water also leads to off-flavour in food fish (Jhingran, 199 Lovern 1; Helfrich and Newcomb, 2009).

Turbidity

Increase in the turbidity in the season of rain as a result of profound soil degradation and suspended materials from sewage which affect river and aquatic organism (Verma et al., 1984). Flow of water and turbidity are often related (EPA, 2012). Higher turbidity leads to less penetration of light to the lower levels of water and this decreases the plant productivity in the floor of water and subsequently dissolved oxygen of aquatic reserve (Perlman, 2014). Upper level of turbidity can reduce visibility, feeding behaviours and ultimately physically spoil the aquatic life. The natural movements and migrations of aquatic populations may disrupt by the solids in suspension (MDEQ, 2017).

During the investigation, similar finding is observed in rainy season. In later part of summer and early monsoon season, the turbidity found is not safe for fish growth.

For a healthy aquatic body maximum reading of turbidity is of 2.5 NTU, as proposed by WHO, but it is of 5 NTU by ICMR and BIS (De, 2003). The present findings, the mean finding of turbidity 1.94 NTU, agree that the fishpond is suitable for fish growth.

pH

The pH of water is an index of hydrogen ion (H^+) concentration of water. The mean pH (7.46) value of the study, is slightly alkaline (Sharma, 1981) which lies within the standards of pH maintained by WHO, ICMR, CPCB and BIS. During the present study lowest value of pH of July coincides with utmost value of free CO_2 (10.9 mg l^{-1})

and low value of DO (6.0 mg l^{-1}). This is in agreement with the findings that photosynthetic rate produces the pH above 8 in natural water that requires more CO_2 than supplied by respiration and decomposition (Wani and Subla, 1990). Thus low pH (6.6) results in low DO (6.1 mg l^{-1}).

According to Kumar *et al.* (2014), pH is listed highest during monsoon and least during summer season. The present investigation agrees, with a record of lowest pH during the month of June, July and August due to intense rain of monsoon. Heavy monsoon rain provides fresh supply of free carbon dioxide causing excess production of H^+ ion. A similar finding says, Carbon dioxide being an acidic gas, its concentration greatly influences the pH of natural water (Boyd, 1971; Singh, 2017). In the present study, the mean range of pH is between 6.1-7.4 mg l^{-1} that is ideal for pisciculture. It agrees with the study of Santhosh, Singh (2007) that reveals the appropriate pH range for fish rearing is within 7-9.5, and ideal level is within 7.5-8.5. pH values remains<7.0 from June to September with fluctuations.

From late monsoon (October) pH starts increasing till late winter (January to February) and declines in summer and even in rainy season due to rain and flood. In summer low value is possibly the effect of high-leveled temperature.

Dissolved Oxygen (DO)

The most vital parameter of the water quality and basic requirement of aquatic life is dissolved oxygen (Jhingran, 1952). During different seasons, the DO concentration varies greatly showing seasonal fluctuation throughout the study (John, 1978) with which the present observation agrees.

The rainy season experiences lower value of DO during as a result of high growth of bacteria which used oxygen for metabolic activities (Ahmad and Krishnamurthy, 1990). This can lessen the growth, nourising and frequencies of moulting as well (Boyd, 1990). Low DO is major limiting water quality parameter in an aquaculture system (Boyd, 1995; Singh, 2017). The Findings of the study with low mean of dissolved oxygen in rain (5.4 mg l^{-1}) agrees.

According to Pandey *et al.* (1992); Gupta and Sharma (1995) DO concentration is elevated in the winter is due to utmost concentration of autotrophs, high rate of photosynthesis and automatic release of oxygen. The unit to express the O_2 concentration in water is ppm which is equivalent to mg l^{-1}(Boguski, 2006; Stone *et al*., 2013).

The present investigation displays highly momentous seasonal rise and fall from 4.7 mg l^{-1} to 8.2 mg l^{-1}. The maximum value (7.41 mg l^{-1}) of DO is recorded in winter, but lower value in summer (7.03 mg l^{-1}) while lowest value is found in rainy season (5.4 mg l^{-1}). During season of rain, the DO is down and remains lower till in late summer but during winter and biginning part of summer it is higher. Similar observation is noted by Sahni and Yadav (2012) from Bharawas pond of Riwari, Haryana.

As stated by Chaurasia and Pandey (2007), amount of DO in aquatic body directly or not directly dependent on temperature of water and partial air pressure. In winter maximum dissolved oxygen during the investigation, is may be due to utmost dissolution of oxygen and increased rate of photosynthesis. It agrees that more cold the water, the more O_2 can dissolve in the water and so, DO concentrations at one site are generally lower in the summer than in the winter (Murphy, 2007).

Concentrations of O_2 gradually increases become higher because of the interaction of rain fall with O_2 in the air. More sunlight and warmer temperatures also bring increased activity levels in plant and animal life; depending on what organisms are present, this may increase or decrease the DO concentration.

Lessening of DO in water is because of elevated temperature and enhanced activity of microbes (Kataria et al., 2006). The present findings of low DO in summer agrees with the explanation that the respiratory rate intensifies along with the raise of temperature, activity and after feeding; but reduces with increasing mean weight (Singh, 2017), which leads to decrease in DO value. The key source of oxygen for respiration of fish is air of atmosphere and photosynthesis of planktons.

Free Carbon dioxide

The respiratory activity of aquatic animals contributes free CO_2 which is a highly soluble gas in water. The quantity of carbon dioxide imparts certain specific effect on

aquatic biotic assembly. Throughout the study free CO_2 is present in the sample pond. Respiration of biotic community adds $CO_2$to thepond. Conversion of some amount of CO_2 into bicarbonate brings a slight change in pH (Hutchinson, 1957; Golterman, 1975; Talling, 2010). Generally the CO_2 in free form develops in water bodies when oxygen content is low or absent.

In the present study the lowest value(3.8 mg l^{-1}) of free carbon dioxide is found in January (winter) and highest value (10.9 mg l^{-1}) in July(summer). The temperature that leads to bacterial growth, accelerates the process of decay of organic matter then photosynthetic activity (Voznay, 1981; Naik, 2014) of organisms (Jhingran, 1991), results in larger amount of free CO_2 in summer. As suggested by Bhatnagar et al.(2004), 5-8 ppm is necessary to photosynthesize ; 12-15 ppm level is below toxic to fishes and 50-60 ppm is toxic to fishes. In the study the free CO_2 varies between 6.1 mg l^{-1} to 7.4 mg l^{-1}, thus it is in safe range of photosynthetic activity of autotrophs which is an ideal condition for fish growth. This is supported by Santhosh and Singh (2007); Ekudo and Abowei (2011) with their recommended ideal CO_2 level for good fish growth <5 mg l^{-1} and <10 mg l^{-1} respectively.

There may be some relationship of CO_2 with sewage inflow containing factors like organic pollutants and faecal matters of human influence to generate the high organic decomposition (Boralkar, 1981; Wagh and Kamat, 2014). The cause behind high level of free carbon dioxide during early rain and rainy (May to October) is enhnced decomposition rate of organic substnces by the microbes resulting rapid carbon dioxide production (Pandey et al., 1992; Mohapatra and Patra, 2012). The current findings agree with free CO_2 at its pick in summer and rainy season.

As observed by Hazarika (2013) in Assam, comparatively lesser level of free CO_2 in winter is primarily because of photosynthetic activity which utilizes free CO_2. However, the present study agrees with the level of free CO_2 in winter being comparatively low and found to be 3.8 mg l^{-1} to 5.2 mg l^{-1}.

The free CO_2 in the river Mahanadi as studied by Naik (2014), is found to be 3.7 to 11.0 mg l^{-1} which agrees to the present findings (3.8 to 10.9 mg l^{-1}).

Total Alkalinity

Total alkalinity is a crucial parameter to determine the quality of fish pond. The sum total bicarbonates and carbonates is termed as total alkalinity. Alkalinity is decreased or consumed by respiration, nitrification and sulphide oxidation (Stumm and Morgan, 1981; Glynn and Plummer, 2009). In the present study, the total alkalinity value varies between 32.0 mg l^{-1}(rainy) and maximum 119.0 mg l-1 (early summer). This can be due to seasonal effect, plankton population, bottom deposits and water current (Jhingran, 1991; Muniyellappa, 2018).

The study shows extensive range of total alkalinity with maximum value (119.0 mg l^{-1}) is recorded in summer. Its minimum value during season of rain can be because of increased water quantity as rainwater has considerable amount of CO_2 which neutralises with carbonic acid. Similar observations are recorded by Sreenivasan (1976). He observes highest alkalinity during summer which declines subsedquently in the monsoon. Jhingran (1991); Bose and Gorai (1993); Thapa and Pal (2014) also report its low value of rain and high value during summer season. During the study in Binka station of Mahanadi, Naik (2014) observes less macrophytic growth restricted to winter and early summer, when the alkalinity value is more than rainy months, that agrees with the present study. This is supported by (Herbert and Anderson, 1971; Choudhury and Ahi,2014).

During rainy season, the lowest total alkalinity (33.0 mg l^{-1}) is recorded in July. Sreenivasan (1974-79; Choudhury and Ahi,2014) support some of the factors like heavy rainfall, high water level, dilution of water, rocky and sandy bottom area which cause low alkalinity. According to Stone and Thomforde (2004) desirable range is 50-150 mg L-1 (CaCO3); an acceptable range is >20 mg L-1 and <400 mg L-1 for ponds and that is > 10 mg L-1 for hatchery water. Santhosh and Singh (2007) recommend the ideal value for fish culture as 50-300 mg L-1 .These literature studies agree that, the total alkalinity of range 32.0-119 mg l^{-1}andmean value70.46 mg l^{-1} during the study, is safe for fish culture.

The less alkalinity has been reported in the water low in pH level (Dwibedi et al., 1977) and reach in free carbondioxide (Saha, 1981; Laskr and Gupta, 2009).

Total Hardness

The sum of temporary and permanent is the total hardness. Temporary hardness and permanent hardness are due to the presence of bicarbonates and sulphate /chlorides of Ca^{++} and Mg^{++} respectively. Water with< 5.0 mg l^{-1} $CaCO_3$ is not suitable for fish growth as suggested by Jhingran (1991). As per the suggestion of Bhatnagar et al. (2004) the desirable alkalinity is 80-200 ppm and undesirable value is >300ppm due to non-availability of CO_2.

Seasonally average value of calcium during winter, summer and rainy summer season are recorded as 4.57 mg l^{-1}, 6.38 mg l^{-1} and 7.75 mg l^{-1} respectively. Stagnation, low depth of waterbody, human and animal abuses are the causes of greater value of hardness during summer. This is supported by Nayak (1986) and Naik (2014) in their study on river Mahanadi. Increasing trend of total hardness during rainy season may be due to further addition of fertilizers, pesticides, cow dung, sewage waste and human faecal matters from nearby agricultural fields. This agrees to the findings that high concentration of calcium and magnesium in addition to sulphate and nitrate in the sewage waste added during monsoon, may lead to the high value of hardness during monsoon (Angadi et al., 2005). But it contradicts the findings of high TH in monsoon by Nayak (1986) and Naik (2014).

A total hardness of $CaCO_3$ is classified by the Sawyer et al. (2003); Suresh et al. (2007) as CaCO3 equivalents, into TH < 75 as safe, 75–150 as moderate–hard, 150–300 as hard , > 300 as extremely hard. So, the study pond with total hardness 121.1 mg l^{-1}, is considered as moderately hard which is suitable for fish growth.

Calcium

Calcium is considered as vital parameter as well as micronutrient in a water body. Its increase contributes to hardness in water making it in poor condition for use (Saxsena,

1987; Khanna and Singh, 2002). This investigation reveales a variation of calcium concentration of the sample pond, from 3.3 (winter) to 9.5 mg l^{-1} (rainy).

The observations of Suresh et al. (2007) record greatest quantity of calcium in the water of Lahru Pond during rain and minimum in winter. The current study also reveals similar findings: lower value of calcium during winter (3.3 mg l^{-1} to 5.6 mg l^{-1}) , higher value during monsoon (6.5 mg l^{-1} to 9.5 mg l^{-1}) and gradual increase of values in summer (4.4 mg l^{-1} to 8.4 mg l^{-1}). This agrees to the observation of Naik (2014); Angadi et al.(2015) that calcium is lower in summer months, increases in monsoon, reduces again in winter and during late summer it gradually enhances. As recommended by U. S. Environmental Protector Agency (EPA)(1986) ; Tafa and Assefa (2014) maximum level of 10 mg l^{-1} calcium in potable water is safe for human consumption which agrees the present findings measuring highest Calcium concentration of 9.5 mg l^{-1}. As per observations, Calcium level within 10.0 mg l^{-1} is an index of medium productivity which indicates that the study pond is moderately productive (Naik, 2014).

Other physicochemical parameters

Chlorophyll biosynthesis of flora and enzymatic transformations particularly for phosphorylation in algae, fungi and bacteria require Magnesium as a major micronutrient. According to Kulkarni et al. (1983) total hardness of water increases due to elevated concentration of Mg. Dagaonkevi and Saksena (1992) reveal that Magnesium performs the key in growth of chlorophyll and work as a limiting factor for development of phytoplankton. The study oqf Sahni and Yadav (2012) shows that Magnesium concentration is noticed beyond the permitted value (50 mg l^{-1}) of WHO. In the current study Mg value recorded 34 mg l^{-1} which proves that the medium is suitable fish growth.

The studies of Nyamangara et al. (2013), amount of nitrate is a major concern in the aquatic body that is used as drinking water for human and livestock.ICMR, WHO, BIS has prescribed the range of Nitrate-Nitrogen as 20, 45, 45 mg L^{-1} separately. The level of sulphate during study is 20 mg l^{-1} which is within the permissible value and agrees to these literature studies. But it is higher than the recommended value (0.1mg $l^{-1}$to 4.0 mg l^{-1}) for fish growth (Santhosh and Singh, 2007). Nitrate is however non-toxic to

fish and it is not a serious health problem except at exceeding high levels (more than 90 mg $l^{-1}NO_3$-N) (Stone et al., 2013). Nitrogen is primary necessity of all organism for the basic processes of their life such as protein synthesis, growth and reproduction.

Phosphorus is a very important element for the animal and plant growth. Phosphate is formed out of this element.The foremost source of phosphate is the maximum use of fertilizer in agricultural or residential cultivated land which enters into surface waters with storm runoff (Nguyen et al., 2013).The maximum limit for phosphate and phosphorus is 0.1 mg l^{-1} (US EPA, 1986).The present mean phosphate concentration 0.07mg l^{-1} falls within this limit which mark the pond under study is appropriate for rearing of fish.

Chloride concentration can be an important parameter for detection of contamination by sewage (Padhy et al., 2018). In this study mean Chloride concentration (63 mg l^{-1}) is safe for aquaculture and this agrees with Stone and Thomforde (2004). According to them the wanted levels of Chlorides for cat fish production in commercial basis is above 60 mg l^{-1}. Potassium and sodium concentration is found to be 63 mg $l^{-1}$and 2.1 mg l^{-1} which is quite essential for fish growth.

In some waters only bicarbonate alkalinity may found and not carbonate alkalinity. Whatever production method may be used, the buffering system of carbonate is vital to the fish farmer in good fish farming, where photosynthesis primary natural source of oxygen is photosynthesis, and leftover carbon dioxide is stored as carbonates and bicarbonates. The level of bicarbonate and carbonate during the study are recorded 150 mg $l^{-1}$and 20 mg l^{-1} respectively, which together contributes to the desirable level of total alkalinity.

PLANKTON

phytoplankton

During the course of the present investigation three major groups of phytoplankton are in count: Bacillariophyceae, Chlorophyceae and Myxophyceae which agrees with the findings of Mohanta (2000), Patra (2002) ,Naik (2014), Nair *et al.(*2015). A quite similar finding is recorded by Kumari et al. (2018) and Das et al. (2018), where

phytoplankton of the water body is represented by four major group of algae: Chlorophyceae, Bacillariophyceae, Myxophyceae and Euglenoophyceae .‘ .

Well diverse seasonal fluctuation comes to light in the present study. Among the phytoplanktons, Bacillariophyceae occupied the highest place which agrees with the investigation of Bisht (1993). Several species of Bacillariophyceae has high oxygen demand but also tolerate alkaline sediment. Such species are not altered with human disturbances (Fore and Graft, 2002). Species of Bacillariophyceae are met in every part of the study which goes with the above findings.

As per the reports of Mohanta (2000), lowest count of plankton in rainy season might be the result of cloudy weather and muddy water which hinders the penetration of light into the pond.During winter, decline of phytoplankton community may lead to least photosynthetic activity, maximum level of surplus CO_2, minimum dissolved O_2, maximum pH and high total alkalinity. However, reverse findings of winter may be the result of phytoplankton abundance. Thus, the results of the present work reveals that any change in algae count can be linked to the water quality parameters such as pH, phosphorus and nitrogen (Winer and Duthie, 2000).

Moderate temperature, less turbidity and transparency are the favourable conditions during winter which raise the count of phytoplankton to the peak.The study is supported by Mukherjee et al.,2010 with their detailed record of phytoplankton dynamics of a lake in Ranchi. They encounter relatively least distribution of phytoplankton in March, May and August but abundance of all variant phytoplankton blooms in month of in November.Giripunje et al.(2013) agree with this finding with the observation that during monsoon, inflow of rain water and wave action of water currents acts as limiting factors for phytoplankton population. Similar findings were recorded by Naik (2014) in the river Mahanadi.

The highest phytoplankton population is found in winter when turbidity is low; water is clear and greenish. During rainy season due to high turbiditythe muddy coloured water supports lowest planktonic population. These findings of present work, reveals similarity with findings of Khanna et al. (1993); Chatterjee *et al.* (2014) and Naik (2014).

Literature shows that Ganapati et al. (1953); Verma et al. (2014)and Arumugam et al. (2015)report peak values of Cyanophyceae when temperature and pH were high. Present study agrees with the peak value of Mixophyceae noticed both the years during summer. Season wise plankton count reports highest count of Chlorophyceae and Bacillariophyceae) in winter.

Moderate temperature, less turbidity and transparency are the favourable conditions during winter which raise the count of phytoplankton to the peak.The study is supported by Mukherjee et al.,2010 through the detailed record of phytoplankton dynamics of a lake in Ranchi. They encounter relatively least distribution of phytoplankton in March, May and August but abundance of all variant phytoplankton blooms in month of November.Giripunje et al.(2013) agree with this finding with the observation that during monsoon, inflow of rain water and wave action of water currents acts as limiting factors for phytoplankton population. Similar findings are recorded by Naik (2014) in the river Mahanadi.

Several species of Bacillariophyceae has high oxygen demand but also tolerate alkaline sediment. Such species are not altered with human disturbances (Fore and Graft,2002). Species of Bacillariophyceae are met in every part of the study which goes with the above findings.In the present study, the dominant member in terms of count among Bacillariophyceaewas *Diatoma* as it is collected from the sample pond throughout the year. Similar observation is found by Arumugam et al. (2015).

Megalef's index measures richness of species in an ecosystem. In the present study Megalef's index (d) was (3.10) during October which agrees with findings of Brraich and Kaur (2015) during their study in Nangal Wetland, Punjab. But maximum value of Margalef's Index in the present study is (7.12) during August which contradicts the findings of Brraich and Kaur (2015), where maximum value was observed during January.

Sarif et al. (2017) find that maximum Equitability index (j) value at Bhola is 0.99 during monsoon season. This agrees with findings of the present study that maximum value of Equitability Index in the month of August during monsoon period.

Shannon diversity index (Hs) is used to characterize species diversity in a community. According to Mc Donald (2003), the index value between 1.5 and 3.5 has low diversity and value > 3.5 has high diversity and species richness. The highest Hs of phytoplankton was recorded at (1.517) during monsoon season and lowest value (0.35) during post-monsoon season. Findings of present study agree with highest Hs value in August (3.02) and lowest value in post monsoon period.Rajagopal et al. (2010) reported that due to dilution of water in rainy season, the low value of Shannon's index of phytoplankton population is observed (Shruthi and Rajasekhar (2013). So, phytoplankton abundance, density, diversity and distribution are related to changes, due to variation in the hydrological conditions in coastal waters.

Zooplankton

During the course of present investigation among all the groups of zooplanktons, the dominant species is recorded to be *Daphnia.*

Minimum count is quite common during rainy. The most dominant group is Cladocera followed by Protozoa, Rotifera, Copepoda and Ostracoda (Naik, 2014).

In the present study, zooplankton population of different groups is maximum during both in winter and summer. However, minimum count is found during rainy season. Similar findings were noted by Kumar et al. (2011) during his study on tropical pond of Bihar. The present study shows that zooplankton comprises of Protozoa, Rotifer, Cladocera, Copepode and Ostracoda. During the rainy season of the study,sudden reduction in zooplankton population can be due to sudden fall of temperature and dilution in concentration of minerals and salts in wetland water(Sukumar et al.,2013)

In the present study zooplankton population shows both unimodal as well as bimodal peak. The population of different group is maximum during both winter and summer. However, minimum count is always found during rainy season (Naik, 2014).

Plankton abundance in relation to the physicochemical parameter of Mancharibele reservoir in Bangalore district is studied by Sukumaran and Das (2002). In his

investigation zooplankton comprises of four major groups including Protozoa, Rotifera, Cladocera and Copepoda. Present study reveals similar findings with four major groups of zooplankton with both unimodal as well as biomodal peak and minimum count is always found during rainy season.The dominant zooplankton group is Cladocera followed by Protozoa, Rotifera, Copepoda and Ostracoda.During the present study, Copepoda is represented by only two species: *Mesocyclops* and *Neodiaptomus*. They are found during summer and winter but not during rainy season. According to Takamura et al., (1989) Rotifers in the water body acted as indicator of eutrophication.Das (2002) during his study on shrimps of Odisha finds that density of zooplankton population is influenced by the season and copepods and rotifers are the dominant groups among all collected samples. In his research he shows that density of zooplankton was minimal in rainy and summer season.The current study with similar observation agrees.

But the present study considers free living Copepoda are essential link in food chain. In the present study, Copepoda is represented by single species *Cypridopsis* rarely found in summer and in winter and not in rainy season. During rainy season (July to October) population of zooplankton is minimum due to dilution of water. Their population is greatly affected by agricultural irrigation, surface run off and soil erosion. According to Harvey et al. (1935) increase in Copepod population is accompanied by the reduction of diatom number as later is consumed by the former. Similar findings of present study show that Diatoms dominate the phytoplankton count whereas the Copepods are few in number and due to less Copepods, the Diatom population is high (Padmakumara, 2010).

The number of species and the eveness of their distribution among taxa are together represented by Shannon-Weaver index (Hs). The findings of Shannon index of Bhat et al.(2014) on Bhoj wetland states that Shannon index fluctuates between 0.96 and 3.75 and classified it as less diversed as Hs is >2. According to Mc Donald (2003), the index value between 1.5 and 3.5 has low diversity and value > 3.5 has high diversity and species richness. The present investigation agrees with the findings of with Hs varied from 0.63 – 2.04 and the sample pond is identified to have low diversity as Hs >2.

PRIMARY PRODUCTIVITY

The measurement of primary productivity apart from giving information about production of organic matter in an area per unit time, it also throws light on functional aspects of the ecosystem (Odum, 1971; Dash *et al.*, 2011).

The ratio of NPP and GPP is highest (0.78g C m^3h^{-1}) in winter and lowest (0.43g C m^3h^{-1}) in rainy season. A similar observation is studied by Ahmed et al. (2005). Seasonally, Dash et al. (2011) has recorded the maximum GPP in summer season and minimum is recorded during rainy season in all the six stations of Kharasrota river of Odisha. The current study renders the same opinionof maximum GPP (0.937±0.102 g C m^3h^{-1}) during the summer season (March) and minimum GPP(0.075±0.007 g C m^3h^{-1}) during monsoon (September).The increase in GPP and NPP are favoured by high alkalinity and hardness during post monsoon period.Concurrently, Mishra et al. (2012) suggests high concentration ofnutrients, higher temperature and higher photosynthesis during the pre-summer and summer months may be responsible for the higher primary productivity found in hisstudy.

The ratio of net and gross primary productivity is important for the calculation of the amount of gross productivity available to the first trophic level consumer (Singh and Singh, 1999; Dash et al., 2011).

The highest (0.78) ratio of NPP and GPP is recorded in winter and lowest (0.43) in rainy season.In the present study, CR percentage of GPP is observed to be highest (0.52) during rainy season and lowest in winter season. Thus ratio of NPP and CR is minimum (0.49) in rainy season and maximum (7.09) during summer. Findings of Dash *et al.*(2011); (Mishra *et al.*,2012) has supported this study. According to them, clarity of water and suitable temperature that favour high phytoplankton concentration and more photosynthetic activities, may cause the NPP:CR value >1 during winter. This ratio is <1 during monsoon, may be on account of less penetration of light into the water due to increased suspended particles resulting in lesser phytoplankton count and photosynthetic activity.

During winter, lessening of CR value can be linked with low temperature and reduced light affecting the rate of photosynthetic efficiency (Sinha et al., 1990 and

Salathia et al., 2007). During summer, the values of community respiration are higher which may be due to high water temperature that stimulates the growth of microorganism population, in term more oxygen is utilised for their metabolic activities (Naik, 2014). Increase in CR, due to the flow of organic detritus along with flood water (Dash *et al.*, 2011). CR and nitrate are positively related where as CR and pH were negatively related which may be due to abundance of bacteria (Naik, 2014).

MORPHOMETRIC FEATURES

The knowledge on biology of fish particularly morphometry, length-weight relationship, condition factor, GSI, GnSI, HIS, breeding behaviour, food and feeding have highest importance in the management of fish products (Evans, 2000; Russel and Yonge, 2002; Das et al.,2014). The study of comparative size at maturity of *P.obscura* states that maturity of fish depends on growth (Odo et al., 2012).

Throughout the present investigation, 540 numbers (270 male and 270 female) of Indian major carps (*L.rohita*, *C.mrigala* and *C.catla*) are observed in three age groups: young, mature and mature but adult. This view has been supported by similar study of Rajguru (1992) during various stages of maturity (immature, maturing and matured) in *C.lida* (Khlil *and Ibrahim.*, 2016). Morphological observations and body measurements are conducted on ten females and ten male to study the allometric growth patterns by Coban et al.(2012).

Analysis of average body weight, body length and standard length of the Indian major carps in the present investigation shows no significant difference among them, neither season wise nor sex wise. But in the present study of fish, significant difference observed between BW, TL and SL with highest mean body weight (504.85± 12.28 g) in *C.catla*, highest total length (36.47± 0.42 cm) in C.mrigla and highest standard length (28.26± 0.36 cm) in *C.catla*. So lengthwise, *C.mrigla*is dominant among three species of carps of the present study.Basic information on fish biology can be predicted from length, weight relationship. Thus, it is necessary to estimate the weight of the fish from its length (Frose et al., 1998; Koutrakis and Tsikliras, 2003; Chitrakar and Parajuli, 2017). The present investigation reveals that, with the increase of age the average body weight

and length increase. This may indicate that the whole body of an Indian major carp grow symmetrically with respect to its body length and weight.

The highest body weight is attained in spawning season of the present study due to enlargement of ovaries. This agrees with linear values found by Hussain (2009). Islam et al. (2012) observe similar peak of body length and gonad weight during monsoon in Gangetic Whiting, *Sillaginopsis panijus* which strengthen the study. BW of carps has positive correlation with TL($r=0.963$ at $p\leq 0.01$) and SL ($r=0.919$ at $p\leq 0.01$). Moreover, all the morphometric parameters are significantly correlated at $p\leq 0.01$ and $p\leq 0.05$ level. However, there is no significant correlation or negative correlation (summer) of GW with STW at $p\leq 0.01$level .The low gonad weight of carps coincides with high feeding activity (Coban et al,2012). This is supported by the information that that during the period of maturation of gonad the feeding activity of fish ceases and lows downto a great extent at the time of spawning (Alkahem and et al.2002).

Throughout the investigation in the average values of LHF1, LAF1 and LF1CP showed diverse type of significant difference among them. LH values of *L.rohita* is lower (12.72± 0.13 cm) than both *C.mrigla* and *C.catla*. Similarly highest value of LAF1 and LF1CP is attained by *C.catla* and *C.mrigala* respectively. Along with the increase of age, mean of these biometric traits also increase with highest value in A3 group of fishes (Zakeria and Vadelal, 2003)

In the present study of length of fins of three species of total 540 number of fishes are measured. It is observed that species wise *L.rohita* and *C.mrigla* have no significant difference in average values of length of all fins. Age wise length of all the fins remains longest in A3 group throughout the study. No significant difference was observed in the length of different fins of three carps species.

In the present study species wise the measure average distance between different fins of three species of carps under study records significantly different values except in DEF2 which is of almost same value in the three species. Age wise highest distant values are displayed in A3 group (Odo et al, 2012).

In the present study width of the body of carps are measured in three different areas namely WF1MF2, WF1F3 and WF1F4. The average values of these widths almost significantly different among the three species but highest values are found in *C.catla*. Thus in present investigation lengthwise highest average is displayed in *C.mrigla* and girth (width) wise highest average is displayed in *C.catla*(Suresh et al., 2006);.Al Hussaini ,2007).

As per the length of air bladder (ABL1 and ABL2) and its weight (ABW) of the major carps of present study, ABL1 and ABL2 of three species display diversity. However, the weight of air bladder of *C.mrigla* and *C.catla* display no significant difference but both values are significantly different from ABW of *L.rohita*. Ona (1990) finds that both size and shape of the swim bladder can be modified by changes in stomach content, gonad development, fat content of fish. Highest mean values ABL1, ABL2 and ABW are found during rainy season agree.

Seasonwise highest average of stomach weight (SW) (2.14± 0.099 g) and liver weight LW(5.73± 0.22 g) in winter season. During present study LW(5.73± 0.22 g) and GW (7.55±1.44 g) averages reach their peaks in winter and rainy season respectively. Average of kidney weight declined in summer season (1.34 ± 0.06 g). Species wise highest value of heart weight (HW) (0.05± 0.02 g), liver weight (5.90±0.21 g), kidney weight (1.75± 0.08 g) are observed in *C.catla*. Heaviest gonads (10.28± 2.08 g) are recorded in *C.mrigala*. It concludes that though *C.catla* organ size was large but gonads of *C.mrigala* is heaviest. Average weight of the gonads in the present study are solely due to the weight of pair of ovaries as pair of testes of males have negligible weight (0.02± 0.002g).

Average of stomach weight (SW) of carps declined during spawning season (1.67± 0.08g) as feeding activity ceases in rainy season. Similar findings are observed by Alkahem et al., (2002).

The condition factor reveals the condition of fish in relation to the surrounding. During rainy season, condition factor (K) (2.25± 0.07, Gastrosomatic index (GSI) (0.67± 0.17), Gonadosomatic index (GnSI) (1.45 ± 0.75) during rainy season. This findings of

present study reveals that during spawning period, condition (K) of the carps remain optimum. Highest mean value HSI is encountered in summer season (prespawning period) when GSI value is low (0.36± 0.036).An inverse relationship between GSI/HIS and breeding cycle of Female *C. arel*isexhibited with lowest values observed during peak-spawning in January (Rajaguru, 1992), which supportsby the present findings of highest GSI in summer and lowest HSI in summer and highest HIS and lowest GSI in rainy. GSI of *C. punctatus* varies from 1.0- 3.5 which supports the readings of HIS. The GSI of the study is particularly helpful in identifying days and seasons of spawning, as the ovaries of gravid females swiftly increase in size just prior to breeding season

(Abdullah and Lohar,2011).

During the study period highest K value as observed by *C.catla* reveals that in the sample pond *C.catla* attains the highest optimum condition of living among the three species. Mean GSI value of *C.catla* also remain in peak which reveals that highest percentage of body weight of *C.catla* was occupied by stomach weight in comparison to two other species. Mean HSI value of *C.mrigla* (1.21± 0.23) explains that liver weight value remains highest in relation to body weight.(Chonder, 1999). It is supported by the similar studies of Kamanga et al. (2002) whichexplain the effect of temperature on gonadosomatic index of *Oreochromis karongae*.

The present study revealed gradual enhancement of biometric traits and biological parameters shows gradual increase in values and highest values in age group three.

Correlation analysis of present study reveals that there is a significant and positive correlation among allometric parameters except the fact that kidney weight is negatively correlated with gonad weight throughout the study.

As per the percentage analysis of anatomical traits concerned, HW of carps cover same percentage (0.10%) of BW with respect to the seasons, species, age groups and sexes under the present investigation, which finds no difference. Highest STL per cent (3.1 %) of the body weight is found in A1 group which indicates that major portion body weight in young fishes is due to the length of the stomach in comparison to adult ones. It

is interesting to note that the STL per cent of BW (2.18%) in females is higher than that of male counterparts. (Rajguru ,1992;Coban et al; Khlil *et al.*, 2016)

Highest percentage of BW is provided by the STW (0.45%) in winter season and in A3 group (0.398%) of fish and lowest STW per cent in rainy season (0.35%). The highest per cent of stomach weight in winter may be due to increase in feeding intensity in correspondence to phytoplankton abundance and low breeding activities. Season wise minimum LW per cent of BW (0.93%) is encountered in rainy season which may be due to the contribution of liver content towards spawning activities (Pradhan, 2014; Chitrakar and Parajuli, 2017).

Season wise maximum and minimum per cent of GW per cent of BW are found in monsoon (1.58%) and winter season (0.30%) respectively. It could be explained that in winter gonads proliferate for spawning and they gradually decrease to minimum size in summer. The GW percent of BW of females (2.125) is much higher than males which may be due to negligible size of the testes in comparison to ovaries. This finding is supported by the similar study of Keivany and Soofiani (2004) on stomach contents, egg diameter, relative and absolute fecundity in the Zagros tooth carp. Highest per cent of KW of BW (0.34 %) of carps in winter may be due to enhanced feeding activity in suitable conditions in the aquatic medium (Kumar and Siddiqui, 1989: Zakeria and Videlad, 2003).

Throughout the study *Catla catla* dominate in percent of LW and KW percent of body weight.

BIOCHEMICAL ANALYSIS

Alike variation patterns and comparable range are detected in basic biochemical composition of muscle and liver of three Indian major carps. The biochemical composition of test fishes collected hasshown season, species and age specific pattern in their muscle protein and lipid contents.These findings of present study agree to with observation Jayaram et al. (1980); Abdullah and Lohar (2011) that *Catla catla*, *Labeo*

rohita and *Cyprinus carprio* grown under same conditions of environment are not significantly different in there chemical composition.

Water temperature easily affect the body temperature, growth rate, feeding and metabolic function of fish as it is a poikilothermal animal (Britz et al., 1997; Hossain et al 2012). The present study showed the higher rate of growth and activity in warmer season(summer) than the colder season due to decline in feeding and metabolic rate (Sahu et al.,2007; Pradhan, 2014). Accordingly similar observations are made on growth rate and activity of the major carp, which shows that water temperature acts as a variable regulate significantly (Hassan, 1996; Sahu et al.2007).

Nutritional values of a fish species in comparison to others can be assessed by proximal biochemical composition of that species. Comparison of intra and inter species composition values of muscle and liver of the three carps *C.catla, C.mrigala* and *L.rohita,* explains that fishes remain content with nutrients and energy during growing season.

In the present study the biochemical components like: moisture, protein, ash and lipid are analysed. Usually the live weight of the fish comprises roughly of 70-80 percent ofwater, 20-30 percent of protein and 2-12 percent lipid (Love 1970). The study agrees with the range of principal biochemical constituents are moisture (68.7– 81%), protein (10.4 – 18.5%), ash (0.6 - 1.5%, lipid (1.0 - 4.5 %) in fishes. This range of biochemical constituents are parallel to those of Jaequot (1961): moisture (66 - 84%), protein (15 - 24%), ash (0.8 - 2%, lipid (0.1 -22 %). A large portion of fish body muscular tissue thus it has economic importance. Findings of Jarwa and Bhuyan (2016) are also supportive to present findings. The maximum portion of fish body is occupied by muscular tissue in contrary to any other vertebrate and the major component of it is moisture. In rainy season the moisture content of muscle and liver of Indian major carps displays increasing trend which matches with increase in total hardness, calcium and salinity in water.

In this study moisture content has an inverse relation with the amount of lipid variation. Seasonal variation of liver, moisture inversely varies with gonad maturation

(rainy season). In *Diplodus pintozzo*, Hernadaz et al. (2003) and Coban et al. (2012) observe similar result.

The increase in the fat content during the breeding may be due to the fact that the fish is ready to spawn and there is an increase in nutrient sources with the increase in temperature. Similar results were also reported by other workers (Jyrwa and Bhuyan,2016).There is a well-marked moisture content in the Indian major carps in relation to GnSI, may be due to use of more body to develop gonad (Pradhan et al, 2012). Maximum values of moisture content in *Mugil cephalus* in rainy season could be due to fall of feeding when water would be highly turbid and it is irrespective of weight group, sex and season (Das, 1978). Fluctuation in the moisture level has been related with breeding cycle (Love, 1960; Pandey et al. 1976; Nargis, 2006). The present investigation explains that moisture content of muscle and liver of three Indian major carps are related to lipid level change directly and feeding intensity indirectly.

Ash is the major of mineral content in fish .Irrespective of the species; males possess more ash than females. Fish as a source of mineral nutrition has been vividly discussed by Causeret (1962).The present analysis reported age wise at the late of maturity, the ash content decreases. Different researchers have different views in this regard. As per the report of McBride and Maclead (1959) in *Oncorhynchus ishawytscha*, muscle of small fish has more salt like sodium in comparison to medium and large size fish.

Protein is next dominant bio-chemical component in muscle and liver of Indian major carps. More protein values are in winter and gradually decrease in summer and rain when mature fishes are in maximum number (Pradhan et al, 2012).

In both sexes protein content increases as higher value obtained in *L.rohita* and lower in *C. mrigala*. According to Singh et al. (2005) mobilisation of protein and lipid occurs for ovarian development of *Labeo dyochelius.*The protein content in females in rainy season is recorded lower in comparison to their counter parts. This finding is supported by Jyrwa and Bhuyan (2016). They encounter the highest protein content of the

tissue is highest in all the seasons indicating that the protein was the major biochemical constituent of the fish meat. The findings of the study agree with it.

Lipid as an important constituent, evaluate the quality of fish meat (Caulton and Bursell, 1977, Marais *et al*., 1990). As per the present study liver contain more lipid than the muscle and liver of *C.catla* contains highest amount of lipid than other two species. Lipid content increases with increase of age and body weight. Hassan (1996) compared the lipid content of wild and cultured fishes.

Towards maturity the lipid declines in fish muscle and liver. This may be due to mobility of body lipid in this phase. The percentage reduction is more in female. Low level of lipid recorded in rainy season which is parallel to reproductive season. The feeding intensity of fish depends on size, season, food availability, and maturity stage (Datta and Das, 1983). According to present investigation, lipid content of the body remains low in A1 group and most fast fat accumulation in A3 group. Carbohydrates and other components due to their negligible amount are overlooked in this study (Love et al., 1964; Caulton and Bursell, 1977; Marais *et al*. 1990).