5.1 Habitat ecology of fish:

Wetlands can produce up to eight times as much plant matter as wheat fields (Jhingran, 1991). The productivity of a water body is generally determined by physico-chemical qualities of water and soil of that water body. A wetland has some specific characteristics like the lower regime of dissolved oxygen concentration, higher water temperature, high turbidity and macrophyte vegetation. Floodplain wetlands are shallow enough due to which light penetrates up to the bottom and increases plankton and macrophyte densities. The chemical quality of water of floodplain wetland depends mainly on bottom soil, vegetation, salinity, pH, minerals, nutrient contents and pollutants. Some of these, such as vegetation, nutrient contents etc. depend upon physical factors. Both physical and chemical characteristics determine the dissolved gases viz. $O_2$, which is a major limiting factor for fish production. (Dixitulu, 1981; Yadava et al., 1987; Rana et al., 1996; Pathak, 1997).
Temperature is basically an important factor in aquatic medium which determines the quality of water to a large extent and for its effect on chemical and biological reactions in water. It influences the aquatic life and concentration of dissolved gases. Besides, temperature is also considered to play an important role in some physiological processes like release of stimuli for breeding mechanism in aquatic fauna and controls behavioural characteristics of organisms. Temperature regulates various physico-chemical as well as biological activities of a water body. The average minimum air temperature was found in December and that of maximum was recorded in September. On the other hand, maximum air temperature was found in September and minimum was in January. Both air and water temperature was increased gradually from January to September (Fig. 5(A)). In overall, low temperature reduces the rate of biochemical, thermo chemical and enzymatic reactions. The fluctuations of water temperature were found in accordance with the seasonal changes of atmospheric temperature. Again, the mean surface water temperature was observed to be lower than the atmospheric temperature in all the months, indicating a strong influence on the former by the later and is more evident in the case of shallow stagnant water body (0.973). Similar trend was also observed in the study of Ahmad & Siddiqui (1996), Shastri & Pendse, (2001), Sunkad & Patil, (2004) and Kumar & Sharma (2005).
The water temperature and the air temperature were directly correlated. Further, both atmospheric and water temperature was found to be positively correlated and also with all other the parameters except alkalinity. The findings of the present study have similarity with the observations made in other Indian floodplain lakes (Yadava & Dey, 1990; Singh & Roy, 1990; Sinha et al., 1994; Devi et al., 2007).

Fig. 5(A) Seasonal variation of air and water temperature

The water temperature plays an important role in either decreasing or increasing the concentration of certain chemical characteristics, largely influenced by local climatic conditions. Maximum productivity of the plant was obtained during monsoon probably due to increase in temperature and rainfall resulting favouring propagation and growth of biota living in the aquatic system, which leads to increased biological
reactions and reduces solubility of gases (Raghuwanshi, 2005).

Temperatures not only affect physiological processes, but also affect the density and stratification of water, solubility of gases and salts in water. The water temperature also plays an important role in controlling the occurrence and abundance of phytoplankton (Nazneen, 1980). A rise in temperature of water accelerates chemical reactions, reduces solubility of gases, amplifies taste and colour and elevates metabolic activity of organisms (Shrivastava & Patil, 2002).

The pH is important since the aquatic organisms are well adapted to a specific pH range and do not withstand abrupt changes in it (George, 1997). pH is a scale of intensity of acidity or alkalinity and measures the concentration of hydrogen ions in water. The pH of water fluctuated within neutral to slightly alkaline range throughout the period of study. In the present study, higher value of pH was observed during July while, lower value was during December (Fig. 5(B)). However, these values were within permissible limit of pH 9.5 (WHO, 1998) and of pH 6.5 to 8.5 as per the ISS standards (BIS, 1982). Hora & Pillay (1982) reported that a pH between 7 and 8 is characteristic of good water, suitable to fish life. According to Banerjee (1967), pH ranging between 6.5 and 7.5 provides most favourable productive condition for fish. Sayeswara et al., (2011) reported the values of pH were within permissible limit of 6.5 to 8.5 as per the Bureau of Indian Standards (BIS, 1982). Acid waters reduce
the appetite of the fish, their growth and tolerance to toxic substances. It renders the fish prone to attack of parasites and diseases.

The pH in ‘Bogeepool’ exhibits some seasonal variability with higher values in monsoon and lower in winter (Fig. 5(C)). The pH showed direct correlation with atmospheric and water temperature, free carbon dioxide, dissolved oxygen and alkalinity. High value of pH indicates alkaline nature of water which is higher in monsoon in comparison to pre and post-monsoon seasons. It is due to high rate of evaporation in monsoon and due to high photosynthesis of micro and macro-vegetation resulting in high production of DO shifting the equilibrium towards alkaline side. Beyond pH 8.5, the water can affect the mucous membranes of fish (Prajapati & Raol, 2006) and air pollution also tends to lower the pH of rainwater (Sharma & Chandel, 2006). Fortunately, Dibrugarh and its surrounding area are relatively free from SO₂ and other inorganic pollutants as there is no industry in the vicinity of the studied wetland.

Increase in pH may be associated with increase in DO produced as a result of photosynthesis as has been emphasized by Sreenivasan (1967a, b), Unni (1972), Sehgal (1980) and Khajuria (1992). Decrease in pH is in accordance with the decline in CO₃ concentration and rise in HCO₃ content. The pH values observed in the present study were in the same range as reported earlier for other Indian lakes (Tiwari, 1999; Patil et al.)
As pH value of 6.5 to 8.5 is recommended for drinking purpose the water of Bogeepool can be considered as potable use also.

Dissolved oxygen (DO) is essential for the metabolic activity of aquatic organisms. The presence of oxygen is due to the direct diffusion from air and photosynthetic activity of autotrophs. The oxygen plays very important role in regulating metabolic processes of both plants and animals and indicates purity of water and reflects the physical and biological process prevailing in the water. The dissolved oxygen regulates the survival of aquatic life. The variations of DO depend on the primary production and respiration of aquatic organisms. In the present study, highest value of DO was recorded in April and lowest in November (Fig. 25). DO was found directly correlated with all the studied parameters except alkalinity and free carbon dioxide. The values of dissolved oxygen in Bogeepool were above the tolerance limit (5 mg/l) as prescribed by BIS (1982). Thus, the dissolved oxygen content of Bogeepool seems to be quite suitable for fish production. The temporal variation of DO level depended mainly on temperature, light penetration, rainfall, climate etc. Apart from this it also depended on the primary production and respiration of the aquatic organisms present in the environment (Dhas, 1991).
The high DO was recorded during August and that of the lowest during November. The DO was recorded highest during monsoon season while lowest during winter {Fig. 5(C)}. The relatively high DO may be due to the impact of rain water resulting in aeration and rich growth of submerged macro-phytes including algal flora in super abundance number. Fall in DO level during winter may be due to mud metabolism, metabolism of biotic micro-invertebrates and vertebrates, scum formation and cessation of photosynthesis due to algal cover of the water surface and low miscibility of gases in water (Jhingran, 1975, Khalaf & McDonald, 1975) at higher temperature. The low DO values was found during winter as a result of the accumulation of oxygen demanding effluents and domestic sewage from Byramangala lake, Bangalore (Ram & Mohan, 2007).

According to Banerjee (1967), the concentration of dissolved oxygen (>7 mg/l) provides a healthy environment to fish. Oxygen can be rapidly removed from the water by discharge of oxygen demanding wastes (Shrivastava & Patil, 2002). The levels of dissolved oxygen in freshwater lakes reflect the habitat quality and are a significant factor affecting distribution, species composition, and abundance of organisms in the biological community.
Free carbon dioxide (FCO₂) converts insoluble carbonate (CO₃²⁻) into soluble bicarbonate (HCO₃⁻). In the present study, maximum FCO₂
was recorded during May and minimum was during November {Fig. 5(C)}. The variation of CO$_2$ was due to its absorption by plants for photosynthesis and also exhalation of other living organism. The high CO$_2$ value is due to the entry of organic and inorganic nutrients from the surrounding areas. Further, free carbon dioxide was found to be negatively correlated with DO and alkalinity while positively correlated with atmosphere and water temperature.

The variation of CO$_2$ is due to its absorption by plants in photosynthesis and activity of other living organisms. Free CO$_2$ helps in buffering the aquatic environment against rapid fluctuations in the acidity or alkalinity and also regulates biological process of aquatic communities (Prasannakumari et al., 2003). Highest value of FCO$_2$ was observed during post-monsoon and lowest was during pre-monsoon {Fig. 5(C)}. But, Pal (2008) viewed that the minimum value of free CO$_2$ in post monsoon might be due to maximum utilization of it by phytoplankton.

The alkalinity in the water is primarily a function of carbonate, bicarbonate and hydroxide contents. Alkalinity of water is a measure of weak acid present in it and of the cations balanced against them (Sverdrup et al., 1942). Alkalinity of water is its capacity to neutralize a strong acid and is characterized by the presence of hydroxyl ions capable of combining with hydrogen ions. In natural waters most of the alkalinity
is caused due to the free carbon dioxide. According to Kaur et al., (1996) high alkalinity values are indicative of the eutrophic nature of the water body. The water is mainly dependent for its total alkalinity on cations of Ca, Mg, Na, K, NH₃ and Fe occurring in combination with the carbonates and or bicarbonates or occasional hydroxides. The maximum value of alkalinity was recorded during May and minimum in April (Fig. 5(D)). In the present study, surface alkalinity may result from waste discharge of local households and from the nearby paddy fields. It was found that the value of alkalinity is within permissible limits of 600mg/l. Higher alkalinity level in certain months of the year is an indicative of high productivity of the water body (Bogeepool). For surface water, alkalinity may result from waste discharged from industries and microbial decomposition of organic matter present in the water body (Abbasi et al.,1997). Several workers have recorded dilution of alkalinity with the advent of rains (Chakraborty et al. 1959; Goldman & Wetzel 1963; Sreenivasan et al., 1997) and its increase with decrease in water level (Subha Rao & Govind 1964; Swarup & Singh 1979). The present findings on alkalinity were well within the range as reported by other workers for Indian lakes (Radhika et al., 1999; Rasool et al., 2003 and Kudari et al., 2004).
Alkalinity showed negative correlation with atmospheric and water temperature, FCO₂ and dissolved oxygen, but directly correlated with pH. In the present study, alkalinity was recorded highest during pre-monsoon and lowest in post-monsoon [Fig. 5(E)]. According to Spence (1964), the lake having alkalinity more than 60 ppm may be considered nutrient rich. Banerjee (1967) believes that alkalinity above 20 ppm does not appear to influence fish production.
5.1.2. *Plankton density:*

Phytoplankton is integral components of freshwater wetlands, which significantly contribute towards succession and dynamics of zooplankton and fish (Payne 1997). In an aquatic system, phytoplankton are major producer and important among aquatic flora. They are ecologically significant as they serves as ecological indicators and act as secondary host for a number of fish parasite (Hoffman, 1967) and form the basic link in the food chain of aquatic animals. The study of plankton as an index of water quality with respect to industrial, municipal and domestic pollution has been reported earlier (Baruah *et al.*, 1994; Acharjee *et al.*, 1995; Jha *et al.*, 1997). Vincke (1979) reported ecological
condition of rice-field and noticed a high fertility rich fauna and flora, especially rich phytoplankton as compared to many fish culture pond.

Community structure, dominance and seasonality of phytoplankton in tropical wetlands are highly variable and are functions of nutrient status, water level, morphometry of the underlying substrate and other regional factors (Gopal & Zutshi 1998; Agostinho et al., 2001). Recently, Saikia (2010) reported 7 categories of aquatic macrofauna and 4 types of aquatic macrophytes from a rice-field of Kaloogaon in Sivasagar district, Assam. Shallow water bodies like beels and inundated rice fields have relatively high nutrients and as such have a rich planktonic biota. Plankton is very sensitive to the environment they live. Any alteration in the environment leads to the change in the plankton communities in terms of tolerance, abundance, diversity and dominance in the habitat. Therefore, density and diversity of plankton be used as a reliable tool for biomonitoring studies to assess the pollution status of aquatic bodies (Mathivanan et al., 2007). The studied water body, Bogeepool although perennial, is a relatively shallow flood plain lake that harbours a wide array of planktonic organisms. In the present study, overall abundance of phytoplankton was higher during monsoon season. Similar observation was found by Muzaffar & Ahmed (2007) where phytoplankton was abundant between June and August. They further noted that with the
progressing season, the nutrients likely become depleted causing the significant reductions in the phytoplankton richness and abundance as the water levels started to subside in September.

5.2.1. Length-weight relationship:

Length–weight relationships give information on the condition and growth patterns of fish (Bagenal & Tesch, 1978a). The overall length-weight relationships of five fish species showed allometric growth curves. The exponential value ‘b’ was less than ‘3’ in both males and females but better conditions in females than males (Fig. 6 A-E). It showed that both the sexes of the fish, the regression coefficient ‘b’ is significantly different from ‘3’ suggesting a deviation from the so called cube law and it shows that the fish grows at a higher rate than the cube of the length. Thakur & Das (1974) stated that the value of an exponent significantly greater than ‘3’ or less than ‘3’ denoted that it did not maintain the isometric (b=3) pattern of growth. This means that if the exponent is less than 3, the species becomes lighter for its length as it grows larger and conversely, if greater than 3, the species becomes heavier for its length as it grows in length.

The ideal value of b= 3.0 indicates the fish are having the isometric growth of equal increment of both parameters (Allen, 1938). However, Hille (1936) and Martin (1949) reported the value of regression
coefficient ‘b’ lies between 2.5 and 4.0. Again, Bagenal & Tesch (1978b), Koutrakis & Tsikliras (2003) reported that value of ‘b’ might be in between 2.0 and 4.0. However, Wootton (1992) provides a rough idea on this situation, indicating that allometric growth is negative (b<3) if the fish gets relatively thinner as it grows larger and positive (b>3) if it gets plumper as it grows. The regression co-efficient for isometric growth is ‘3’ and values greater or less than ‘3’ indicate allometric growth (Gayanilo & Pauly, 1997).

Though the “b” value depends primarily on the shape and fatness of the specimen studied, other factors like temperature, food quality, quantity and food size, sex, time of year and stage of maturity also contribute its fluctuation (Pauly, 1983; Sparre, 1992; Cherif et al., 2008). The value of ‘b’ may be different due to feeding, sex and maturity state. If the fish retains same shape and specific gravity, it remains unchanged during lifetime (Laghari, et al., 2009).

The exact relationship between length and weight differs among fish species according to their inherited body shape, and within a species according to the condition (robustness) of individuals, sometimes reflected by the food availability and growth within the weeks prior to sampling (Yousuf & Khurshid, 2008). The intercept ‘a’ of all the length groups and seasonal was negative which indicates a perfect linear
relationship between the variables. The value of ‘b’ may change with localities, sex and maturity with metamorphosis (LeCren, 1951). Higher values of ‘b’ (> 3) were reported in carps (Chakrabarty & Singh 1963; Bhatnagar 1972). While exponential values ‘b’ less than 3 were reported in major carps (Rao & Rao 1972; Kulshrestha et al., 1993). The length weight relationship shows that the values of ‘b’ was found to be less than 3 in different species and even in the same species from different water bodies (Khan, 1988; Yousuf et al., 1992). The variations in the exponential value (b) might be due to composite culture and certain environmental conditions (Narejo et al., 2003).

(a)
Fig. 6 (A). Length-weight relationship of male (a) and female (b) *C. gachua*.
Fig. 6(B). Length-weight relationships of male (a) and female (b) *P. sophore*
Fig. 6 (C). Length-weight relationships of male (a) and female (b) *P. ticto*
Fig. 6(D). Length-weight relationship of male (a) and female (b) *T. fasciata*
Fig. 6 (E). Length-weight relationship of male (a) and female (b) of T. sota

5.2.2 Condition factor (K) of different fish specimens

During the present study the value of K showed fluctuations in all length groups of males and females in all the fish species. In Channa gachua, highest ‘K’ value was found at 5-8cm size group in males and at 8-11 cm in case of female. However, the lowest ‘K’ was recorded in 11-14cm length group of males and in 5-8 cm for females. In case of T. fasciata, highest values of ‘K’ were recorded at 4.5-5.5cm in both the sexes, while the lowest in 8.5-9.5cm for males and in 6.5-7.5cm for females. Similarly, highest ‘K’ values were found in 3-3.5 cm for males and in 2.5-3 cm for females in T. sota. Lowest ‘K’ was recorded in 4-4.5 cm for males and in 3-3.5 cm for females in the same species. For P.
sophore, maximum values of ‘K’ were recorded in 4-5 cm for both males and females, while minimum were in 6-7 cm for males and 5-6 cm for females. In case of *P. ticto*, highest ‘K’ was recorded in 4.5-5 cm for males and lowest in 3.5-4 cm. But it was highest in 5-5.5 cm and lowest in 3.5-4 cm for females. According to Bakare (1970) and Welcomme (1979), condition factor decreases with increase in length and also influences the reproductive cycle in fish. The decrease in condition factor with increasing length of the species might be due to slower growth as it is expected that most of the energy derived by the fish has been channelized for gonadal development. The decrease in ‘K’ in the higher length group of species with irrespective of sexes may be associated with sexual maturity or spawning phase (Rao & Rao, 1972; Desai, 1973). Olurin & Aderibigbe (2006) worked on juvenile *Oreochromis niloticus* and were observed to be in good condition, as the values were higher than one.

The variations in the condition factor may be attributed to different factors, such as environmental condition, food availability and the gonadal maturity (LeCren, 1951; Bashirullah, 1975). This indicates that condition factor is not only influenced by the maturation of the gonads and the food presents in the alimentary canal, but may be due to seasons. K also gives information when comparing two populations living in certain feeding, density, climate, and other conditions; when determining
the period of gonad maturation; and when following up the degree of feeding activity of a species to verify whether it is making good use of its feeding source (Weatherley, 1972, Abowei, 2010).

5.3. Food and feeding habit:

5.3.1. Morphometry:

Alimentary canal of fishes exhibits a higher degree of variation than that of any other group of vertebrates. The feeding habit of the adult fish becomes apparent when a single organ or a few organs are examined (Suyehiro, 1942). Al-Hussaini (1949) observed that in Mugil tade, the length of the alimentary canal varies with the nature of the food consumed in different environments, where algae formed the predominant food, the alimentary canal is found to be longer, with a well-developed pyloric stomach and a long gastro-intestinal canal with specially organized mucosa. The adaptation of the alimentary canal and certain external morphology of the species greatly influence its ecology and ethology of the food and feeding and regimes (Thomas, 1966).

In the present study, C. gachua has short and uncoiled alimentary canal indicating carnivorous feeding habit, whereas in P. sophore and P. ticto, the gut is long and moderately coiled indicating omnivore feeding habit, In case of T. fasciata and T. sota showed long and highly coiled alimentary canals indicating herbivore in feeding habit. It was also
observed that except in *Channa gachua*, all the other fish species were having small gape of the mouth and compact gill filaments. In *C. gachua*, however, the alimentary canal is much shorter than body length, the gape is relatively wider and so also the gill filaments.

5.3.2. *Seasonal variation in gastosomatic index (GSI)*:

The feeding intensity (GSI) of *Channa gachua*, *Puntius ticto*, *P. ticto* and *Trichogaster fasciata* was lower during winter but during pre-monsoon in case of *P. sophore* and *T. sota* for males while during winter in *P. sophore*, *P. ticto*, *T. fasciata* and *T. sota* but during pre-monsoon for females of *C. gachua*. However, higher GSI was observed in post-monsoon in all fish species except *C. gachua* and *P. ticto*. Mojumdar (1969) and Mojumdar & Dan (1981) also reported low feeding intensity in *Tachysurus thalassinus* and *T. tenuispinis* during their breeding season. It may be because more intensive sexual stress in females than that of males as observed by Khumar & Siddiqui (1989).

Slight differences was observed in the seasonal feeding intensity of both the sexes in all the studied fish. It may be related to food abundance in a particular season and also to predominance of immature and maturing fishes which feed actively. Distinctive decline in feeding activity for both the sexes of the studied fish during winter (Dec-Feb) can be attributed to recovering stages of gonads as well as low temperature of water and non
availability of preferred food. The intake of food subject to variations of preferred food items from season to season. In the present study, feeding intensity in female specimens of all the studied fish was invariably poor during spawning season. Such variation in feeding intensity in gravid fishes was described as ‘spawning fast’ and noticed by many workers (Biswas, 1982; Singh, 2011).

5.3.2 Relative length of the gut (RLG):

Al-Hussaini (1949) reported that the length of the gut is compensated by the average mucosal area and short gut may be compensated by longer mucosal folds. Das & Moitra (1956) have shown that a constant ratio exists between the gut length and the total length for each species of fish from the same water source. Relative lengths of guts (RLG) showed that all the species except *C. gachua* have RLG value greater than 1 which indicates these fish species are either herbivorous or omnivorous in their feeding habit. In the studied fish species, the RLG value was found almost constant with the increase in length of the fish. RLG value has close relationship with the nature of food of the fish (Das & Moitra, 1956). The length of the intestine of the fish depends upon the feeding habits. Barrington (1957) has suggested that more than one factor are responsible for determining the relative length of the alimentary canal. The low RLG value shows that the fish falls in the category of
carnivorous fishes. Carnivore fishes normally have short and more or less straight intestine. This is because the meat gets digested more easily (Pandey & Shukla, 2005; Serajuddin & Ali, 2005) wherein herbivores fishes the intestine is long and highly coiled because the vegetable food items take more time for digestion. The intermediate condition is found in omnivores. Dasgupta (2011) reported RLG values of *P. sophore* and *T. fasciata* as 1.68 and 3.11 respectively. However, this value for the same fish species was found relatively higher in the present study probably due to size differences in fish species under study in two areas of Assam and West Bengal.

5.4. Reproductive Biology

5.4.1. Sex ratio:

Information on the sex ratio of a population is important for more than one reason. Generally, a sex ratio of bisexual species is close to 1:1 (Swarup & Singh, 1979). However, the sex ratio of different month reveals that a wide variation between males and females in all the five species (Fig 7 A-E).
Fig. 7 (A) Monthly variation in sex ratio of *Channa gachua*

Fig. 7 (B) Monthly variation in sex ratio of *P. sophore*
Fig. 7 (C) Monthly variation in sex ratio of *P. ticto*

Fig. 7 (D) Monthly variation in sex ratio of *T. fasciata*
Fig. 7 (E) Monthly variation in sex ratio of *T. sota*

Deviations from 1:1 sex ratio are not to be commonly expected, as it would represent a disadvantage for the individuals producing more of one sex on the available of partners for its breed (Hamilton, 1967). The concept of 1:1 sex ratio was confirmed by Jhingran (1968) in *Catla catla*, Fryer & Iles (1972) in cichlid fishes, Pathani (1978) in *Tor tor*, Singh (1978) in *Labeo dero* and Jhingran & Khan (1979) in *Cirrhinus mrigala*.

Mojumdar & Dan (1978) also reported variations in sex ratio of *Tachysurus thalassinus* during spawning period. Reddy (1979a) studied the sex ratio of *Channa punctata* and found that the sex ratio was differed significantly from the theoretical 1:1 ratio. Deviation in the sex ratio were also reported by Nikaido *et al.*, (1991); Wu & Kuo (1993); Ramon
& Bailey (1996); and Chu, (1999) in various species of Thunnus. The variation in sex ratio is probably due to difference in age and size at first maturity, gear selectivity in relation to sex difference in age and also due to differences in natural and fishing mortality between the two sexes (Annappaswamy et al., 2008). Further, differences in sex ratio may result from differential habitat occupation of males and females of the fish species.

5.4.2. Maturity stages:

The formulation of an accurate gonadal maturation stages is very important to understand the reproductive ecology (Giora, 2004). Morphologically, the immature testes did not differ much from the immature ovaries either in shape or size except that they were cream coloured. The testes, however, do not occupy the body cavity as much as the ovaries. The mature testes, unlike the mature ovaries, were fringed and filled with milky spermatic fluid. Similar observations have also been reported by Nautiyal & Lal (1985).

Five different maturity stages were identified in the studied fish species. Qasim (1973) viewed that in tropical and subtropical forms, the classification of gonads should be limited to about 5 maturity stages and in continuous spawners it may be reduced from 5 to 3. Nautiyal & Lal (1985) also described five maturity stages (I-V) in Tor putitora. In C. gachua, immature males and females were found during winter and pre-
monsoon while maturing stages of both the sexes were observed throughout the year. However, dominance of ripe males and females were observed during monsoon season in both the sexes.

In *P. sophore*, immature individuals were mostly observed in winter and pre-monsoon months, developing or maturing stages almost round the year. The percentage of immature stages gonads of both the sexes in *P. ticto* was occurred during winter and pre-monsoon and a small percentages in monsoon season also. However, majority of mature specimens were observed during monsoon and post-monsoon.

Similarly, in both *T. fasciata* and *T. sota*, majority of males were matured during monsoon and post-monsoon and during pre-monsoon, monsoon and post-monsoon for females.


### 5.4.2. Gonado-somatic ratio of the five fish:

The gonadosomatic ratio (GSR) is an indicator of the seasonal development of the gonads. The GSR has been a useful index for monitoring the development of gametogenesis in teleost fish. As in other teleost, the GSR reaches its peak prior to spawning. In the present study too, higher GSR values occurred during the prespawning period and
declined sharply thereafter, indicating that gametes were released. However, the values of GSR have been found higher in female fishes as compared to the male fishes in all kinds of species.

In *Channa gachua*, maximum GSR was recorded during monsoon in both males and females; while the minimum was during winter for both. The GSR was higher during monsoon and pre-monsoon for male and females of *P. sophore* respectively, but it was lower during post-monsoon for both the sexes. For *P. ticto*, it was higher during monsoon for males and pre-monsoon for females but lower was found during pre-monsoon for males and post-monsoon for females. In case of *T. fasciata*, higher values of GSR were reported during pre-monsoon for both males and females, while the lower values were found during winter for males and post-monsoon for females. The GSR values of *T. sota* were found to be higher during monsoon and lower during winter in both the sexes.

The GSR values for males in five fish species were increased from March onwards and subsequently decreased from September onwards and became very low in November/December (Fig. 8 A-E). However, GSR for females increased from February onwards and reached its peak in May for *P. sophore* and *T. fasciata* and in June for *C. gachua, P. ticto* and *T. sota*. The value dropped down from September onwards in all the four fish species except *T. sota* (October onwards). Most fishes in Northern India have been reported to spawn during June to September, which are
the peak monsoon months (Qasim & Qayyum, 1961). The observations on the prolonged breeding season in different fish species were reported by many authors like Nzioka (1979), Aiken (1983), Islam (2004), Sahayak (2005), Vinci et al. (2005) and Annappaswamy et al., (2008).

Fig. 8 (A) Monthly variation in GSR of *C. gachua*

Fig. 8 (B) Monthly variation in GSR of *P. sophore*
Fig. 8 (C) Monthly variation in GSR of *P. ticto*

Fig. 8 (D) Monthly variation in GSR of *T. fasciata*
Fig. 8 (E) Monthly variation in GSR of *T. sota*

5.4.3. Fecundity:

Fecundity is very important in biology of fishes to understand the variation in the level of population as well as to make efforts to increase the amount of harvest. A thorough knowledge of the fecundity of a fish is essential for evaluating the commercial potentialities of its stock, life history, practical culture and actual management of the fishery (Lagler, 1956; Doha & Hye, 1970; Pankhurst, 1998). In the present study, except *C. gachua*, high fecundity was recorded in *Puntius* and *Trichogaster* spp. The low fecundity of *C. gachua* as observed in the present study might be due to prolonged breeding season or parental care rendered by the
species. However, Reddy (1979b) revealed the fecundity of *Channa punctata* ranged from 2,200 to 33,873 with length groups of 12.1-22.3cm.

It was observed that in some cases, larger sized fishes were less fecund than the smaller sized fishes (Islam & Talbot, 1968). Hossain (1997) reported that the fishes of the same size might show great variation in their fecundity due to the multi-spawning pattern of the small fish species. However, in the present study, higher fecundity was observed in the increase in length and weight of the fishes. Nikolsky (1969) reported that the fecundity of a population or species is automatically adjusted to food supply by metabolism. Bagenal & Braum (1978) & Annappaswamy *et al.*, (2008) had reported that fecundity in fish species characteristically varied among individuals of the same size and age. Fagade *et al.*, (1984) had also suggested that variations in fecundity may be due to differential abundance of food. Jayasankar (1990) reported the fecundity in *Signanus canaliculatus* varied irrespective of the length or body weight of the fish and increased with ovary weight while the fecundity depends on the availability of body cavity keep mature ovaries and on the size of oocytes (Vazzoler, 1996). The fecundity of a species is also dependent on egg size and high fecundity is often correlated with small egg size and vice versa (Rath, 2000). Narejo *et al.*, (2002) observed that fecundity of spiny eel was mainly dependent on their total length and
body weight while Cognato & Fialho (2006) reported that greater fishes tend towards to have higher fecundity.

The variations of fecundity is very common in fishes and the number of eggs produced by an individual female is dependent on various factors, like size, age, types of species of the samples and their ecological habitats including food availability (Moyle & Cech, 2000). The analysis of relative fecundity aims to reduce the influence of body size of fish in fecundity, allowing comparison between individuals of different sizes. Relative fecundity is an indirect way to estimate the energetic effort used to produce oocyte (Giora, 2004).

5.4.4. Ova diameter:

In the present study, all the species except *T. sota* showed prolonged breeding period extending from March to October. The occurrence of ova was completely absent in December to February indicating that spawning was over. The frequency of maturing and mature ova was again raised from March onwards. As all the fish except *T. sota* showed prolonged breeding period from March to September, it can be concluded that the fish spawns once in a year. Similar observation was also found by Mitra *et al.*, (2007) in *T. fasciata*.

The ovary of maturing eggs in the present study was light orange coloured and ripe eggs were generally yellowish/light greenish coloured. Many workers were also recorded the variation of colours shown by fish
(Bhatnagar 1964; Qayyum & Qasim, 1964 and Rai, 1967). The unequal lobes of ovary were also described by Desai (1973) in *Tor tor* from Narbada. The progressive change observed in the intra-ovarian diameter for a period not less than a year can give an idea of the spawning periodicity of the fish studies (Biswas, 1993).

5.4.5. Breeding season:

Dominance of ripe ova in the females of all the studied species were observed from May to August. This period can be considered to be the peak months of breeding/spawning. Similar finding was also observed by Menon (1979) in *Tachysurus thalassinus*. Nzioka (1979) encountered ripe specimens of *Abalistes stellatus* during March, August, September and October. Based on the occurrence of spent females and males for over a long period from August to February/March, indicating the spawning period for all five species was over by September. Similar observation was also made by Pathani (1983) in *Tor putitora*.

De Vlaming *et al.* (1982) discussed the utility of GSI as indicators of the reproductive activity of a stock. Afroze & Hossain (1990) studied the sexual maturity and spawning season of *Amblycepharyngodon mola* and they observed that the breeding season of the fish extends from May and continue till October and August is the peak breeding season. Parween *et al.* (1993) observed that the *Esomus danricus* breeds from March to July with a peak in the month of May. Fatema *et al.* (1997) observed that
Oxygaster bacaila breeds from April to August with peak in June and July. The values of GSR and ova diameter in different months support the above studies.

5.4.6. M_{50} determination:

Knowledge on the size at first maturity is useful in the breeding programme. In the present study, both males and females in stage III-IV of maturation were considered as mature for ascertaining the length obtained at first maturity. Only fishes in stage III and above stages were considered to be mature (Raje, 2006). In the present study too, both males and females in stage III-IV of maturation were considered as mature for determination of M_{50}. For C. gachua, all males were found immature at 5-8cm length groups and both sexes were in maturing stage in 8-11 cm length group. The percentage of mature/ripe for males and females gradually increased from 11-14 cm length groups. In case of P. sophore and P. ticto, males and females were immature in 4-5cm and 3-4 cm length groups respectively. Both sexes of P. sophore were in maturing stage in 5-6 cm and higher maturing were found in 6-7 cm length group and mature/ripe gradually decreased in 7-8 cm length groups. However, in P. ticto, maturing of males and females were observed in 4-5 cm and gradually increased in 5-6 cm length groups. Similarly, in T. fasciata and T. sota, immature stages of sexes were recorded in the length groups of 4-
5 and 2-3 cm respectively, while maturing in 6-7cm and 3-4 cm respectively.

The close relationship between maturity and the length of the fish was observed by many investigators (Jayasankar, 1990; Reuben et al., 1993; Dobriyal et al., 2000; El-Agamy et al., 2004; El-Halfawy, 2004; Sahayak, 2005; Raje, 2006; El-Halfawy et al., 2007; Al-Nahdi et al., 2010).

5.5. **Rearing feasibility:**

Breeding and rearing of common exotic live bearers and egg layers fish and culture of small ornamental fish were successfully conducted by Mahapatra et al., (2000) and Ghosh et al., (2003). Similar study was conducted by Sundarabarathy et al., (2004); Marx (2008) and Joshi & Tyagi (2008) in cemented tanks for rearing *Puntius titteya*, *Channa striatus* and carp fry respectively and an increase in length and survival percentage of the rearing fish species were recorded by them.

Survivability is one of the basic criteria for assessing acclimatization (Smit, 1980). In the present study, all the fish species acclimatize well under controlled condition and 100% survival was recorded. Similar observations in acclimatization and feeding habit of *M. pancalus* in aquarium have been reported by Lichtenberger (1985), Ravindranath (1988) and Singh (2011) in *C. striatus* and *M. pancalus* and *M. aral*. 
During the experimental period, few selected physico-chemical parameters were recorded in aquaria water. Water temperature was recorded in between 17 and 22 °C. The pH was recorded between 7.1 and 7.6. According to Hora & Pillay (1982), a slightly alkaline pH of 7-8 is ideal for fish life. The DO was ranged between 4.5 and 5.35 mg/l, while FCO₂ was found between 2.24 and 4.99 mg/l. Total alkalinity was also recorded from 24.7 to 44.09 mg/l. Das & Kalita (2003) conducted the breeding trials of *M. aculeatus* in glass aquarium and maintained the water temperature between 28° and 30° C, pH 7.6-7.8, dissolved oxygen 8-9 ppm and hardness of about 1.5 ppm for healthy growth of the fish. Singh (2011) also reported 100% survival of *M. pancalus* and *M. aral* in glass aquarium by maintaining water temperature between 16° and 22 °C, pH 7.2-7.6 and FCO₂ 1.6 and 2.8 ppm.

5.6. Feeding efficacy:

In the present study, a single *C. gachua* (9.5cm) consumed on an average of 179 larvae per hour. It was also observed that, out of five studied fishes, *C. gachua*, irrespective of size groups consumed highest number of larvae while *T. sota* consumed lowest number of mosquito larvae during all the laboratory trials. The trials also revealed that *P. ticto* and *T. sota* consumed more larvae during daytime than night hours, whereas other three fish species showed better during dark phase. Yadav & Das (1994) found during laboratory trials that *Danio* and *Oryzias*
showed a high predatory efficacy as far as consumption of mosquito larvae was concerned. It was recorded that single individual of *Danio* (2.7-3 cm) consumed on an average of 52 4\textsuperscript{th} instar anopheline larvae per day (24h) whereas, *Oryzias* (2.5 cm) consumed 98 larvae per day. However, it was reported that *Trichogaster trichopteros* can consume up to 47 numbers of *Culex quinquefasciatus* larvae/gram/day (Jayasree & Panicker, 1992). In a study conducted by Homski *et al.*, (1994), revealed that consumption of mosquito larvae by *Aphanius dispar* at instar 4\textsuperscript{th} stage was 5.4 no./fish and 48.3 no./ fish of 26–30mm and 46–50mm respectively. In another experiment in Bangladesh, guppies each ate an average of 41*Culex* larvae/day, with females eating approximately twice as many as males (Elias *et al.*, 1995).

Similar observation on larvicidal behaviour of different fish species were investigated by many workers (Martínez-Ibarra *et al.*, 2002; Mohamed, 2003; Ghosh *et al.*, 2005, Chandra *et al.*, 2008; Al-Akel *et al.*, 2011). Ghosh *et al.*, (2004) worked out experiment on four common aquarium fishes as biocontrol agent in two phases; and their observation revealed that all the fish predators were more active during light phase in comparison to dark phase.

Yildırım & Karacuha (2007) also reported that larger the size of the larvicidal species (*Aphanius chantrei*), higher would be the consumption rate of mosquito larvae. They found that the predation of
mosquito larvae in a 96h experiment with different size groups was 14.8, 55.1 and 123 respectively, indicating larger the size group, more would be the consumption of larvae. Manna et al., (2008) conducted on the vulnerability of mosquito larvae to *Poecilia reticulata* in presence of alternative prey like chironomid larvae and tubificid larvae. They found that *P. reticulata* consumed a good number of mosquito larvae and the consumption rate increased on increase of the body size. In the present study also, the quantum of consumption was found more in larger sized fish whether it is long term or short term exposure.

Cavalcanti et al., (2009) conducted experiment on the efficacy of five different fish as predators of *Aedes aegypti* larvae under controlled conditions and observed that both the sexes of *Trichogaster trichopterus* and *Astynax fasciatus* and the female *Betta splendens* and *Poecilia sphenops* proved to be the most effective predators. He, therefore, concluded that a fish efficacy as a predator depends on its weight and sex among other variables. Meanwhile, Bhattacharjee, et al., (2009) were observed that the prey consumption rate increased as a function of prey density but decreased with container size. They found that *Anabas testudineus*, *Clarias batrachus* and *Heteropneustes fossilis* consumed 14.4–1158.0 fourth-instar mosquito larvae per day.

Earlier studies using the exotic fishes like *Carrasius auratus* (Chatterjee et al., 1997), *Xenentodon cancila* (Chatterjee & Chandra,
1996), *Ctenopharyngodon idella* and *Cyprinus carpio* (Chatterjee *et al*., 2001), *G. affinis* (Chatterjee & Chandra, 1996) and *Oreochromis niloticus niloticus* (Chand & Yadav, 1994; Ghosh *et al*., 2006) and the ornamental fishes *Betta splendens*, *Pseudotropheus trophæops*, *Osphronemus goramy* and *Pterophyllum scalare* (Ghosh *et al*., 2004) have shown predatory ability against mosquito larvae under similar field conditions. Even the indigenous fishes of different genera including *Colisa fasciatus* (Tiwari, 1994) have been found to prey upon mosquito larvae (Sharma & Ghosh, 1994; Chandra *et al*., 2008).

Marti *et al*., (2006) reported the predation efficiency of two neotropical freshwater fish species, *Cnesterodom decemmaculatus* and *Jenynsia multidentata* on *Culex pipiens* L. larvae in drainage ditches in Argentina. They found that both the adult fish species needed approximately 6.2 h to completely digest one *Cx. pipiens* 4th instar larvae under laboratory conditions; but when they were confined with a density of 60 or fewer *Cx. pipiens* 4th instar larvae, the adult fish consumed 100% of them in one day. However, the adult *C. decemmaculatus* and *J. multidentata* consumed only 35% and 42 % respectively when confined with 150 larvae.

The consumption of mosquito larvae at a particular prey density reduced with increased volume of water possibly due to the evasion tactics of the mosquitoes. This is consistent with the observation noted
for the predators like hemipteran bugs (Saha et al., 2007a, b, 2008), and other fishes (Ghosh et al., 2004, 2005). With increment of space, the foraging behavior of the fishes changed and possibly required more time to capture and consume the mosquito preys (Ghosh et al., 2006). Additionally, the active searching processes in these fishes are not prominent as that of the insect predators like the coleopteran Rhantus sikkimensis (Aditya et al., 2006; Aditya & Saha, 2006). Besides, prey density and habitat cover will be probable factors influencing the air-breathing fishes and mosquito larval interactions (Bhattacharjee et al., 2009).

Manna et al., (2008) observed that P. reticulata consumed higher numbers of mosquito larvae at first 10 min and decreased in subsequent time intervals except in 180min for all the length groups. In the present study, the species were found to consume higher numbers of mosquito larvae during first 15min of exposure and subsequently the feeding intensity dropped down as the time passed. However, the feeding intensity showed slight improvement in later part of the experiment. This is probably due to the fact that the experimental fish must have digested a substantial part of the prey food they consumed in early part of the experiment and regained appetite for preying more mosquito larvae.

Sweetman (1958) compiled a world review of habitat and host ranges including both target and non-target species attacked by
introduced biological control agents. However, it was not until the 1980s that biosafety issues gained any traction. The point was strongly made that a lack of proven environmental effects from biological control equates more to lack of study than lack of actual effects, and that really there had been very little effort to investigate non-target effects of biological control (Howarth, 1983). Howarth (1991) therefore, called for an end to ‘ad hoc’ biological control projects stressing instead that introduced agents should be considered guilty until proven innocent and that improvements in protocols for assessing biological control agent introductions were urgently needed. These claims were initially met with disbelief, then hostility. Clarke et al. (1984) documented the extinction of the Partula spp. (Gastropoda: Partulidae) land snails on Moorea by an introduced biological control agent and recommended more stringent oversight, and Turner (1985) described some conflicts of interests associated with the biological control of weeds in North America. Funasaki et al., (1988) reviewed biological control agent releases in Hawaii and showed that 33 agents had been found to attack native non-target species, but claimed that there had been no recorded adverse effects from any biological control program in Hawaii. Simberloff & Stiling (1996) noted that a number of biological control introductions had adversely affected non-target native species but because monitoring of impacts was rarely carried out. Manna et al., (2008) also alarmed prior to applying P. reticulata in fields for strict surveillance of the fish.