CHAPTER V

DISCUSSION
5.1. Fish Biology

5.1.1. Morphometry

The morphometric characters showed a proportional positive increase with increase in length of the fish. The mean and range of these values have been presented in Table 1. Among the meristic characters the number of pectoral, ventral and caudal fin rays were constant. The number of dorsal fin rays, anal fin rays lateral line scales and lateral line transverse scales showed variations without any relation to length of the fish. The average values and the range of variations of the variable meristic characters are shown in Table 2.

The regression coefficient 'b' (Table 3) of different variable characters (Y) on total length (X) indicate that the rate of growth in respect to total length is highest in case of anal length \( b = 0.5961 \) and lowest in case of ventral fin base \( b = 0.036 \). High values of correlation coefficient, 'r' (Table 3) obtained indicates a high degree of positive correlation between the different morphometric parameters with the reference length (total length).

Biometric Index of *N. nandus* indicates that the indices of head length and girth in relation to total length are almost constant (Fig. 3). According to Bayagbona (1963) a constant index in any of the biometric characters in relation to its reference length is isometric. Tiwari and Qureshi (2003) found a linear relationship between total length and morphometric characters *viz.*, standard length, head length, snout length, and depth of body at pectoral fin base in the cat fish, *Rita pavimentata* (Gunther) and also observed that the regression of length and weight did not deviate significantly from cube law indicating isometric growth. Similar observations have been reported by Dasgupta (1989) in *Acrossocheilus hexagonolepis*. The indices of body depth and head depth
increase in relation to total length (Fig. 3). The eye diameter becomes progressively smaller in relation to head length (Fig. 3) and showed negative allometry. A similar case has been reported by Tobor (1974) in *Lates niloticus* and Dasgupta (1989, 1990, 1991 and 1997) in *Acrossocheilus hexagonolepis, Tor tor, Tor putitora and Mystus gulio*. The growth of inter-orbital length and gape in relation to head length was found to be allometric and showed variations. Dasgupta (1990) also reported allometric growth of inter-orbital distance in relation to head length in *Tor tor*.

The use of ‘r’ statistics thus indicated that predorsal length was the most significantly correlated (r = 0.9988) body part of the fish in relation to total length (Table 3). The least significantly correlated (r = 0.9333) body part was the anal fin length (Table 3). The head length was the second highly correlated (r = 0.9986) body part. Nautiyal and Lal (1988) showed predorsal length as the most significantly correlated variable in Garhwal Himalayan Mahseer, while Johal *et al.*, (1994) and Bhatt (1997) found the standard length as the most correlated body part in *Tor putitora* from Gobind sagar reservoir and in the river Ganga between Rishikesh and Hardwar.

In the present study, a high degree of positive correlation was also found among the different head parts with the head length as indicated by high values of correlation coefficient ‘r’ (Table 3). The post-orbital length is the most significantly correlated (r = 0.9969) head part of the fish in relation to head length and gape width is the least correlated (r = 0.9803) variable. Bhatt (1997) reported the eye diameter to be the least correlated variable in *Tor putitora* from the river Ganga between Rishikesh and Hardwar. Negi and Nautiyal (2002) showed snout length and least depth of caudal peduncle to be the most significant linear regression in relation to total length and the parameters showing most significant linear
regression in relation to head length were length of rostral barbel and
length of maxillary barbel in male and female *Barilius bendelisis* and
*Barilius vagra*. He also observed that the body parameters like standard
length and predorsal length were the least significant while head depth
and postorbital distance were observed to show least significant linear
regression in both male and female of *B. Bendelisis* and *B. vogra*. Hamsa
and Kasim (1989) reported that morphometric characters in *Caranx
caranus* revealed that all the four variables, fork length, body depth, eye
diameter and wet weight had a very high significant relationship with total
length. Bhatt *et al.*, (1998) studied the morphometric characters of
Himalayan mahseer *Tor putitora* (Ham.) and found that standard length,
head length, length of anal fin, length of caudal fin, predorsal distance
and preanal distance in proportion to total length and postorbital distance
and preorbital distance in proportion to head length were closely related.

Considerable difference in the morphometric characters has been
observed between males and females of *Nandus nandus* (Table 5). The
males were found to have greater height of dorsal, pectoral, anal, ventral
fins and greater length of caudal peduncle than those of the females. On
the other hand, the females had greater eye diameter, upper and lower
jaw length, body depth and head depth. Similar cases have been reported
by Dasgupta (1989 and 1990) in *A. hexagonolepis* and *Tor tor*. Nikolsky
(1963) has stated that males and females often differ in the length and
shape of the fins. According to him, in the males of many cyprinoids,
both the paired and the unpaired fins are slightly larger than those of the
females, as has been observed in the present study too. He cited
examples of some species where males were found to differ in length and
shape of fins. For example, in the males of certain Lake Baikal Sculpins,
*Cottocomephorus* sp., the thoracic fins were found to be significantly
larger. He further stated that in *Xiphophorus* (Fam. Poeciliidae) there is a
long outgrowth of the caudal fin whereas in the males of many pleuronectes of the family Bothidae, the rays of the dorsal fin are elongated, and so on. In majority of cases the difference in the structure of the fins between males and females is connected with the peculiarities of reproduction. As for example, the dorsal fin of the grayling, *Thymallus* is larger in the male than in the female and increases still further towards the time of spawning, creates a turbulence close to the spawning fish during the spawning process, and delays the dispersal of the sperm by fast currents (Brown, 1938). The larger size of the pelvic fins of the male *Tinch* facilitates a more successful fertilization of the eggs and their attachment to plant stalks (Nikolsky, 1963). Hence such a difference in the morphometric characters of males and females may be represented as sexually dimorphic characters in *Nandus nandus* also.

According to Gould (1966) ratios between morphological characters of fish will not necessarily be constant for the organisms of the same species due to variation resulting from differences in sex, race and nutrition and/or other environmental factors.

Various authors have shown that morphometric characters of fish can vary under the influence of the environment and, in particular, the thermal factor during the period of incubation and the beginning of larval life (Schmidt, 1921 and Barlow, 1961). According to Hubbs (1922) and Tanning (1944) variation occurs in the number of rays in the unpaired fins in several species which is also related to an adaptation to movement of water of various density.

Variation in the body proportions in the same species, according to hydrographic conditions, has also been reported by various authors (Hubbs, 1922 and Barlow, 1961). They associated these variations with the effect of the duration of periods of growth and of the relating differentiations which determines the number of vertebrae and of
segments.

Many authors (Schmidt, 1921; Vladykov, 1934; Tanning, 1944; Lindsay, 1954 and Barlow, 1961) have reported that meristic characters, exhibit plasticity under the influence of environmental factors.

5.1.2. Length-weight relationship and condition factor

The correlation coefficient ‘r’ (0.957) shows a very high degree of correlation between length and weight of *Nandus nandus*.

The exponential value (b) of the length-weight relationship in the present study is greater than ‘3’ thereby indicating isometric growth of the fish. It also indicates that the length-weight relationship in *N. nandus* followed the cube law for isometric growth (Table 6).

The variations in the exponential value ‘b’ is supposed to be under the influence of numerous factors viz., seasonal fluctuations, physiological conditions of the fish at the time of collection, sex, gonadal development and nutritive conditions of the environment of the fishes as reported by Le Cren (1951). Significant variations in ‘b’ values were found in case of juveniles and adults of *N. nandus*.

Lal and Dwivedi (1965), Sekheran (1968) and Dasgupta (1988) have also observed an intra-specific difference in the power function ‘b’ of length in relation to body weight in *Rita rita, Sardinella albeila, S. gibbosa* and *Acrossocheilus hexagonolepis* respectively at different stages of their growth. Hughes *et al.*, (1974) while studying the effect of growth on gills and accessory respiratory organs of *Heteropneustes fossilis* have mentioned the compressed body shape of the fish, a probable cause of the increase of the power function (b = 3.325).

George *et al.*, (1985), Jhingran (1952), Khan and Hussain (1945) found the ‘b’ values greater than 3.0 in case of *Labeo rohita*. Isometric pattern of growth was also observed by Narejo *et al.*, (2002) in
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The exponential values of N. nandus were found to vary in different seasons (summer, monsoon and winter). The 'b' value was found to be highest during monsoon (3.45) and lowest during winter (2.77). During summer the 'b' value was found to be 3.12 (Table 7). Dhasmana and Lal (1993) also reported a significant difference in length-weight relationship in a hill stream fish Garra gotyla gotyla between seasons due to the onset of maturity during the summer months.

Relatively low 'b' value was observed in juveniles of N. nandus and the value was found to be greater than '3' (3.48) in case of adults (Table 6). The seasonal changes and notably the period during and immediately after spawning affect the length-weight relationship. Weight of the gut contents may also alter fish weights depending on the food ingested just before weighing (Muth and Smith, 1974). Beverton and Holt (1957) suggested that the departure of 'b' value from 3.0 is rather rare. Kaur (1981) reported that the departure of 'b' values from 3.0 in case of Channa gachua may be due to the feeding habits of the species and presence of good amounts of detritus along with vegetable matter in the stomach.

The 'b' values for males and females of N. nandus was found to be greater than '3' indicating isometric growth. Chaturbedi (1976) found the
'b' value in *Tor tor* to be 3.16 (male) and 3.39 (female). Similar results were also obtained by Dasgupta (1982) in the exponential value (b) in males and females of *A. hexagonolepis*, by Narejo *et al.*, (2002) in *Monopterus cuchia*.

Pathak (1975) reported that the value of regression coefficient in *Labeo calbasu* was 3.0 from Loni reservoir, M. P. India. AL-Nasiri and Mukhtar (1988) obtained regression coefficient as 3.16 for *Hilsa* males and females obtained from Iraq. Azadi and Naser (1996) reported that the values of 'b' as 3.16 for males and 3.20 for females in *Labeo bata* from Bangladesh. Narejo *et al.*, (1999) calculated the value of 'b' as 3.02 for males and 3.03 for females in *Tenualosa ilisha* from Pakistan. Talwar (1962b) observed that the cube law was very nearly obeyed by females of *Hemirhamphus georgii* but not by the males. Murty (1984) found that there was no significant difference in the length-weight relationship between males and females of *N. mesoprion* from Kakinada. The results of the present study are very similar to the above findings and almost in the same range as reported by Hile (1936), Martin (1949) and Tesch (1968). No significant difference was observed in the length-weight relationship between males and females of *N. nandus* (Table 6).

Narasimham (1970) reported that the value of 'b' increases in the carnivorous fish, *Trichiurus lepturus*, which devours big prey. This may be true in case of *N. nandus* also. Soni and Kathal (1979) reported that the higher value of 'b' (4.36) obtained for *Cirrhinus mrigala* is due to the presence of large quantities of sand and mud in the stomach resulting in an increase in total weight. Hile (1936) and Martin (1949) observed that the values of regression coefficient (b) usually lie between 2.5 and 4.0. Tesch (1968) reported that value of 'b' might be between 2.0 and 4.0. However, a variation in 'b' value may occur due to different environmental factors. Allen (1938) suggested that value of 'b' remains
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constant at 3.0 for an ideal fish and in the present study the 'b' value was found to be 3.135. Hence Nandus nandus can be considered as 'ideal' as per the suggestion of Allen (1938).

Monthwise averages of 'K' have been calculated to elucidate the seasonal fluctuations and has been summarized in Table 9 for N. nandus.

Variations in the condition factor may be attributed to different factors, such as environmental condition, food availability and the gonadal maturity as has also been suggested by many workers (Le Cren, 1951; Jhingran, 1972 and Bashirullah, 1975). According to them study on the changes in the condition value with the increase in length may yield evidences concerning the size at first maturity.

In its variation with the increasing length, the 'K' values in N. nandus showed a peak at length group I (20-40 mm) and thereafter decreased continuously. From length group V (100-120 mm) it again increased steadily reaching a peak at length group VII (140-160 mm) (Fig. 6). From this it can be indicated that juveniles have better condition factor. Many workers (Menon, 1950; Pillay, 1954; Sarojini, 1957; Varghese, 1961) have also observed higher 'K' values in juveniles of either species.

The present results also supports the view of Wheatherley (1972) that even among the members of one population, sampled on a single date, there may be considerable variation in condition with length. According to him, fish populations display considerable changes in average condition, reflecting normal seasonal fluctuations in their metabolic balance and in the pattern of maturation and subsequent release of reproductive products. Even the state of fullness of the alimentary canal may influence 'K' factor (Wheatherley, 1972).

Monthwise fluctuation of K factor showed no specific trend (Fig. 7)
because 'K' factor is not influenced by maturation of gonads only, but other factors also which influences the 'K' factor such as feeding intensity, accumulation of fat in the body etc.

Le Cren (1951) proposed a relative condition factor ($K_n$) and discussed its superiority over condition factor (K). According to him, the former measured all the variations not connected with length, which the latter fails to do unless $n = 3$. Hence, in the present study, $K_n$ values were also studied which showed the same pattern in its variations as the 'K' values with the increasing length of the species showing a peak at length group II (40-60 mm) (Fig. 6). As far as the monthly variations are concerned the $K_n$ values showed almost the same pattern of fluctuation as 'K' values during the first year but during the second year it showed a peak value during September and thereafter it maintained almost similar values with minor variations (Fig. 7).

The relative condition factor ($K_n$) is an indicator of general well-being of the fish; its relative robustness, suitability of habitat and to some extent the size at first maturity and peak period of spawning. 'K_n' values greater than 1 indicate that the general well being of the fish is good. In case of *N. nandus*, the 'K_n' values ranged from 0.91 to 1.28 with an average value of 1.07 which indicated that the general well-being of the fish was good. Shrivastava and Pandey (1981) reported that in Indian major carps the intensity of feeding influenced the condition factor, while the sexual cycle had no direct influence.

The length-frequency distribution histogram shows that the availability of fishes of lower and higher length group is low. The availability of fishes of intermediate size (length groups III-VIII) was higher. Most probably the fishes of lower lengths could not be caught due to larger mesh size of the nets used. Low availability of fishes of higher
length may be due to regular exploitation by the fishermen.

5.1.3. Maturity and spawning

Clark (1934) and Hickling and Rutenberg (1936) were among the pioneers to study the nature of spawning based on size distribution of intra-ovarian eggs in different fishes. Kesteven (1960) discussed in considerable details the utility of gonad maturation studies in fish biology.

The results of maturity studies in *Nandus nandus* indicates that the species has only one breeding season which extends from April to June. However Raizada (1999) reported that the breeding season of *N. nandus* to be from April to September. Das and Zamal (2000) were successful in induced breeding of the fish during May in Bangladesh. Single spawning frequency has been recorded in other species also for example Negi and Dobriyal (1997) recorded single spawning frequency in a hill stream carp *Crossocheilus latius latius* (Ham.), Singh and Agarwal (1986) also recorded single spawning frequency in *Schizothorax plagiostomus* (Heckel). Similar observations were also made by Narejo et al., (2003) in *Monopterus cuchia*, Sudha (2002) in *Mystus vittatus*, Hoda and Qureshi (1989), Rao and Sharma (1984), Bhatt (1971), Sarojini (1958), Prabhu (1956).

In *Nandus nandus*, the frequency distribution of ova at various stages of development between the immature and mature stock was not uniform. The spawning and spent ovaries (stages VI and VII) contained a second batch of ova progressing maturation. The ova diameter study indicated that various sizes of eggs were distributed from immature to mature stock in the ovary which suggests that the individual fish had a prolonged spawning season.

The percentage frequency of fish of different maturity stages and values of gonado-somatic index (GnSI) have also been considered by
Various workers for the determination of breeding season and spawning frequency (Deshmukh, 1973; Sobhana and Nair, 1974; Vasudevappa and James, 1980; Dobriyal and Singh, 1987; Dobriyal, 1989a and b).

Gonado-somatic index (GnSI) when plotted against different lengths (Fig. 15) indicated a tendency for the GnSI to increase with the increase in the body length but this trend is slightly interrupted in length group II. It is also seen that the seasonal peaks (Fig. 14) in the mean GnSI coincided with the peak in the percentage occurrence of mature individuals, hence GnSI can be used as an index of gonadal development. Such a case has also been reported by Kakuda and Nakai (1981) and by Kaur (1981). The GnSI values (Table 10) also showed that gonads were in spent condition from July to September because the GnSI declined rapidly after spawning. The single peak of GnSI in a year indicated that the fish spawned once in a year (annual breeder). According to Kesteven (1942) the gonad maintains a relationship with the remainder of the body of the organisms and since the average size of the maturing or mature ova are constant in general, the number of eggs being a number of units of weight will show an exponential relationship with the length in the same way as does the weight of the entire organism.

The size at first maturity ensures that for yield purpose, the required mesh size net can be used so that the smaller or unspawned fish may have an opportunity to escape out. The method of tabulation of percentage occurrence of mature fish during spawning season have also been made use to calculate size at first maturity by several workers (Thakre and Bapat, 1981 and Nautiyal, 1984).

### 5.1.4. Fecundity

In *Nandus nandus*, fecundity varied from 1106.25 to 37,922.0 in size range of 93 to 145 mm. Mustafa *et al.*, (1980) studied fecundity of *N. nandus* in Bangladesh. He reported that the fecundity of the fish
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ranged from 7381 eggs for a fish with body length 9.7 cm to 46,222 eggs for a fish with body length of 13.5 cm. In case of *N. nandus* the ‘r’ value obtained in the relationships between fecundity and other parameters was found to be highest in case of ovary weight (r = 0.978) and lowest in case of total length (0.75). The ‘r’ value for the relationship between fecundity and total weight was found to be higher (r = 0.83) than the ‘r’ value for the relationship between fecundity and total length (r = 0.75). Kiran and Puttaiah (2003) also indicated that ovary weight was the better index of fecundity than the total length and total weight for *Chela untrahi* (Day) from Bhadra reservoir, Karnataka.

Das (1964) used the comparative fecundity (CF) for evaluating the actual breeding powers of fishes and considered *Mystus bleekeri* with an average fecundity of 15,962 to be a “prolific breeder”; value of CF being 7.03. In *N. nandus* the value of CF was found to be 405.19, so this fish can be considered as a “prolific breeder”. On plotting the fecundity values against body-length (Fig. 16) it has been observed that the egg count increased with the increase in the spread points describing the relationship with increasing size of the fish.

According to Simpson (1951), fecundity is directly proportional to body weight. Bagenal (1967), pointed out that fecundity is more closely connected with the weight of the fish than its length. The number of eggs being a number of units of weight will show an exponential relationship with the entire organism. This has been found to be true in the present
In the present study, the exponential value (in case of the relationship between fecundity and fish length) was found to be 2.716 which approximates the cube law. Fecundity was considered to vary as a square of the fish length (Franz, 1910a & b; Keisseelevitch, 1923; Clark, 1934). Later on Simpson (1951) reported that the egg production to be an internal phenomenon associated with the manner in which the germinal epithelium is folded so as to fill the volume of the ovary thus relating it to the ovary volume and therefore to the cube of the length. Jhingran (1961), Qasim and Qayyum (1963), Bagenel (1967) also found the exponential value to range around 3. in Mystus vittatus, also cube relationship (3.0225) was observed by Malhotra et al., (1979). Higher values of 4.5 in case of Irish Herring (Farren, 1938) or at a rate proportional to fifth power of body length (Hodder, 1965) have been reported. Dasgupta (2002) determined the value to be 5.06 in case of Mystus gulio. Kaliamurthy (1981) determined the value to be 1.15 for the same species from Lake Pulikat. Lower exponential value has also been reported. Dasgupta (1988) reported the exponential value to be 0.5278 for Acrrossocheilus hexagonolepis.

The value of exponent obtained in the relationship between ovary weight and total length of N. nandus was found to be 2.927.

The food consumed by the fish especially the parent population, determines not only the fecundity but also the quality of the sexual products and the viability of the offsprings (Nikolaev, 1958; Nikolsky 1961a & b) thus emphasizing the fish-food relationship, which Ber (1854) saw to be a complex one.
5.1.5. Food and feeding habits

Nikolsky (1963) recognized three main categories of food on the basis of their importance in the diets of fishes. These are as follows:

a) Basic food: which is normally eaten by fish and covering most of the stomach contents.

b) Secondary food: which is found in the stomach, but in smaller amounts, and;

c) Incidental food: which is found rarely in the stomach contents.

Accordingly, semidigested unidentifiable organic matter (35.93%) and prawn and prawn body parts (26.64%) can be considered as the basic food of N. nandus as found in the present study. Fish and fish body parts (10.02%), insect body parts (11.55%), macrophyte tissue (6.55%), semidigested unidentifiable animal matter (3.32%) and insect larva (2.26%) can be regarded as the secondary food. Rotifers (0.04%), nematodes (0.06%), microcrustacea (0.11%), non-parasitic flat worm (0.12%), algae (1.68%), and semidigested unidentifiable vegetable matter (0.25%) can be regarded as incidental items, due to the fact that they formed small portions of the gut content and occurs without any regularity (Table 14).

In the present study, Nandus nandus was found to be highly carnivorous, feeding mainly on prawns, fishes, insects and their larva etc., as well as the species also subsists on rotifers, microcrustaceans, nematodes, worms, filamentous algae, macrophyte tissue, vegetable matter (semidigested and unidentifiable). Semidigested unidentifiable organic matter constituted major portions of the gut content. This may be due to the bottom feeding habit of the fish. Similar to the present study prawns, insect and insect larva were also found in the diets of fishes like Ambassis nama, Ambassis ranga, Mystus cavasius, Wallago attu; aquatic
insects were found in the diets of *Glossogobius giuris*, *Mastocembelus armatus*, *Ompok bimaculatus* (Sukumaran, 2004). Raje (2002) and Vinci (1982) found crustaceans to be the major item in *Nemipterus japonicus*. Serajuddin *et al.* (1998) reported that the food and feeding habits of the spiny eel, *Mastocembelus armatus* showed that macrocrustaceans (specially shrimps) and forage fish were the main food items of adults while annelids, aquatic insects were eaten by young specimens. Kumar (2003) studied the food and feeding habits of *Otolithes cuvieri* (Tre waves) off Veraval and showed that it was a carnivorous feeder, subsisting mainly on *Acetes* sp., penaeid prawns, deep-sea prawns, fishes, stomatopods, molluscs, isopods, copepods and fish larvae and all the size groups were found to prefer crustaceans and the fishes showed preference for teleost fishes as they grew. Jesu *et al.*, (2004) reported food and feeding habits of an endemic catfish *Mystus montanus* (Jerdon) inhabiting river Tambaraparani based on analysis of gut contents and found that small fishes, cladocerans, molluscs, annelid worms, rotifers, insect larvae, copepods, detritus, crustaceans, fish scales, algae and unknown items as food items. Agarwal *et al.*, (1990) reported that the gut content of the snow trout *Schizothoracanthus progastus* from the river Ganga in Garhwal Himalaya contained a large number of insects, their larvae and nymphs. Reddy and Rao (1987) reported that *Mystus vittatus* (Bloch) in the highly polluted Hussain Sagar lake, Hyderabad fed mainly on insect larvae and insects and the other food items included both plant and animal matter. Fishes, prawns, *etc.*, also constituted the food of *C. carangus* as reported by Hamsa and Kasim (1989). Prawns were reported to be the second basic food item in the diet of *Gerres macracanthus* of the Palk Bay and the Gulf of Mannar (Badrudeen and Pillai, 1996). Nayak and Padhi (1998), Kuthalingam (1960) found larval prawns to be the food item in the stomach of the adults of *Sardinella longiceps*.
Basudha and Vishwanath (1999) reported food and feeding habits of an endemic carp, *Osteobrama belangeri* (Val.) in Manipur and showed after analysing their gut contents that the percentage composition of major food items in various size groups of fish was different. A change in diet with increase in size, has been widely reported by Keast (1966), Larsen (1967), De Silva (1973), Adams (1976), Kakuda and Matsumoto (1978). In the present study also, a change in diet has been observed in juveniles and adults. Though prawn and prawn body parts, semidigested fish and fish body parts formed the basic food in case of juveniles of *N. nandus*, quantitatively their percentage decreased considerably in case of adults of *N. nandus* where semidigested unidentifiable organic matter formed the basic food item.

Qualitative studies of the food of *N. nandus* also revealed that the juveniles of *N. nandus* had much more food items in their gut content compared to the adult ones. Rotifers and semidigested unidentifiable vegetable matter were completely absent from the gut contents of the adult *N. nandus*. Microcrustacean, non-parasitic flatworm and nematodes were present in lesser amounts in the adults. Comparision of diets of juveniles and adults were done earlier by Pisolkar and Karamchandani (1981) in *Tor tor* from Govindgarh lake (M.P.), Karamchandani et al., (1967), Desai (1970). The present study also indicates that the percentage of feeding is higher among young individuals than the bigger specimens. This may be owing to the fact that metabolic activities are generally higher in young ones. Similar results have also been reported by Hardy (1924), Marshall et al., (1939), De Silva (1973) and Kaur (1981), Dasgupta (1982) in other fishes also.

In the present study, an inverse relationship has been observed between feeding intensity and gonado-somatic index (Fig. 26) which could be due to the spawning season of the fish, compelling reduced
feeding. Similar view has been expressed by Walfret and Miller (1978) for Northern pike. Jacobson (1974) observed that spawning brings down a sharp decreases in the condition. An inverse relationship between feeding intensity and gonado-somatic index has also been observed by Dasgupta (1982) in *Tor putitora*.

According to Jhingran (1971), the principal factors that are likely to affect the monthly variations in the ponderal index are generally food and sexual maturity. The feeding intensity declined with the progressive maturation of gonads (Fig. 26). Observations on the maturity and breeding season of the species (*N. nandus*) have shown that the fish generally breeds from April to June indicating that the periods of low feeding intensity coincided with the peak spawning season. The low feeding activity during peak breeding season may be attributed to the completely developed gonads, permitting limited space in the abdominal cavity for intake of food. Further it is seen that the feeding intensity increased after the spawning season. Raje (2002) reported that feeding intensity increased as spawning activity decreased in *Nemipterus japonicus*. Gradual increase in feeding intensity in the post-monsoon months has been reported by Acharya and Dwivedi (1984) from the Bombay area. Pathak and Singh (2002) observed high values of feeding rate in *Wallago attu* in pre-monsoon months and after the spawning season and minimum feeding of the fish during the breeding season.

The coincidence of low feeding with peak breeding season has also been observed by many workers. Hardy (1924), Hickling (1933), Faye and Veillet (1938), Menon (1950) and Desai (1970) have reported a decrease in the rate of feeding and amount of food consumed with the maturation of gonads. Bhimchar and George (1952) have also referred to the reduced feeding in Indian Mackerel, *Rastraliger kanagurta* with the progressive maturation of gonads.
The observations have shown that a constant ratio exists between the gut length and total body length for each species of the fish (Das and Moitra, 1955).

The relative length of the gut (RLG) and gastro-somatic index (GSI) values varied according to the size of fishes. During the present study the GSI ranged from 2.68 to 5.07 (Table 18). It was found to decrease in higher length groups (Fig. 24). The RLG values increases with the increasing length of the fishes (Table 21). It is also evident that RLG value has a close relationship with the nature of food of the fish. It is a known fact that vegetable matter requires more time for digestion due to which herbivorous fishes have higher RLG value. In herbivorous fishes such as, *Labeo rohita* and *Labeo gonius* (Das and Moitra, 1956a, b, c; 1958; 1963) the RLG values were about 12.0 and 9.5 respectively. Whereas in omnivorous fishes (Das and Nath, 1965) the RLG values were lower, e.g., *Puntius conchonius* had 3.3 and *Barbus hexastichus* had 2.3. It is reported that carnivorous fishes such as *Bagarius bagarius* and *Notopterus chitala* have low RLG values i.e., less than 1.0 (Das and Moitra, 1956a). Dasgupta (2004) also reported RLG value to be less than 1.0 in some freshwater carnivorous fishes of West Bengal. In the present study, the average RLG values in all the length groups were less than 1.0 (Table 21). Thus, accordingly *N. nandus* can be kept in the category of carnivorous fishes, which is further supported by the results obtained by the food and feeding habits as well as the morphology of the alimentary canal. Morphologically having short, muscular, uncoiled almost straight intestine and large highly muscular stomach indicates towards the carnivorous nature of fish (Dasgupta, 2000). The presence of large quantities of semidigested unidentifiable organic matter in the gut seems to confirm the bottom dwelling habit of the fish. The greater occurrence of semidigested fish and fish body parts in the gut of adults of *N. nandus* suggested that
the larger fishes are mainly piscivorous. Mustafa et al., (1980) studied food and feeding habits of *N. nandus* in Bangladesh and reported that the fish was predominantly carnivorous. Similar piscivorous nature was also reported in *Wallago attu* by Pathak and Singh (2002). Raje (2002), Kuthalingam (1965), Krishnamoorthi (1971) and Vinci (1982) reported such carnivorous and bottom dwelling habit in *Nemipterus japonicus*.

5.1.6. Histological studies of the alimentary canal and digestive gland

Fishes, like other animals require sufficient nutrition for their growth and survival. Feeding behaviour and kinds of organisms taken as food are detected only through the study of the contents in the digestive tract as well as physiological studies. Fishes are also embraced with other aquatic forms occupying different vertical positions (trophic levels) of a food pyramid. *N. nandus* here occupied the position of top predator and placed at the apex of the pyramid in the particular pond ecosystem. Nature offers a great diversity of foods to fishes taken directly through the mouth and then absorbed in a digestive tract. The histological orientation in the digestive tract influences the feeding of fishes. According to their feeding habits they are predators, grazers, food strainers, food suckers and parasites. In the present study *N. nandus* fed on macroscopic animals having well developed grasping and holding mechanism. They are included as predator type. In predatory fishes there is well-defined stomach and strong acid secretion, and the intestine is shorter than that of herbivorous of comparable size (Lagler et al., 1977). Same predatory fishes hunt by sight whereas others depend largely on smell, taste and touch and probably also on their lateral line sense organs to locate and catch their prey.

*N. nandus* exhibits some structural adaptations for grasping and holding the food items. Wide mouth opening of great significance in grasping the large prey; jaw bordered with lips with breaking well-
equipped teeth for holding the prey strongly, it is to be noted that there is a close relationship among kind of dentition, feeding habits and food eaten as also observed in *N. nandus*.

The histological structures of the different region of the alimentary canal were studied in detail to depict the functions of the concerned regions.

In *N. nandus* taste buds are few and much less in number in the buccopharynx. Similar observation was made by Khanna and Mehrotra (1970) in *Muraenesox telabon, Channa striatus, Llisha filigera* and *Pampus argenteus*. The presence or absence of taste buds is related to the mode of feeding (Khanna and Mehrotra, 1970). Fishes have been divided into different groups – i) those feeding by sight only, ii) those feeding by taste only and iii) those feeding by both sight and taste (Bhimachar, 1935 and Mookerji *et al.*, 1950). It appears therefore, that highly predaceous species like *N. nandus* rely more on their sight while feeding. Hence, taste buds are very rare in them. Similar observations were made by Khanna and Mehrotra (1970) in *Muraenesox telabon* and *Harpenden nehereus*.

Mucus-secreting cells or the goblet cells have been reported from the buccopharynx of all teleosts studied so far. It appears that these cells help in trapping the food particles and glueing them together for onward transmission (Al-Hussaini, 1949a; Chaudhury and Khandelwal, 1961). The presence of a very large number of mucus secreting cells indicates that the food is lubricated in this region for easy swallowing and that the main function of buccopharynx is gustation and mucus production, irrespective of the kind of diet of the fish (Al-Hussaini, 1949a).

The mucosal layer of the oesophagus consists of stratified epithelium and numerous mucus secreting cells. In hinder part of the oesophagus, the stratified epithelium gets converted into the columnar epithelium. The saccular mucus secreting cells are present along the sides

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and in the crypts of the mucosal folds and forms a compact, continuous column as found in *Rita rita* (Islam, 1951) and in *Mystus seenghala* (Sarkar, 1959). The main function of the oesophagus, therefore, appears to be secretion of copious mucus to lubricate food for easy swallowing. A mixed stratified and columnar epithelium has been reported in many species of fishes by Girgis (1952), Kapoor (1957a), Pasha (1964a, b, c) and Mehrotra and Khanna (1969). Taste buds are found to be absent in the present study. Similar observations were made by Mahadevan (1950) in *Trichiurus* and *Caranx*, by Ahsan-ul-Islam (1951) in *Rita rita* and *Channa gachua*, by Sarkar (1959) in *Mystus seenghala*. Similar conditions have also been observed in the oesophagus of other teleosts (Al-Hussaini, 1949; Tandon and Goswami, 1968).

The basement membrane below the mucosa is generally thin and submucosa is vascular. In the muscularis, the longitudinal muscle fibres do not form a compact and continuous layer and lie scattered in the form of separate bundles towards the inner side. The longitudinal muscle fibres also extend into the submucosa reaching even into the tips of the blunt villi. This feature appears to be related with the highly predatory habit of the fish, giving stiffness to the mucosal folds and permitting more distension to the oesophagus while swallowing large sized prey.

The gastric mucosa consists of a superficial layer of columnar epithelium and a deeper zone of gastric glands. The columnar cells have been assigned absorptive function by several authors (Green, 1912; Dawes, 1929; Blake, 1936). Al-Hussaini (1946) is of the view that these cells secrete mucus. The mucoid nature of the columnar cells has also been demonstrated by Ahsan-ul-Islam (1951), Kapoor (1957c) and Pasha (1964a, b, c). The present study also shows that the superficial gastric epithelium of the gastric mucosa is mucoid in nature. According to Barrington (1957), these cells are believed to contribute to so called
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"visible mucus" to the total gastric mucin and thus protect the surface of the stomach from the mechanical injury. In the present study, it may however, be concluded that the columnar cells of the superficial epithelium of the stomach in *N. nandus*, probably serve a dual role: secretion of mucus for protecting the superficial lining and absorption of digested food materials. An identical function of the superficial epithelium has also been described by Pasha (1964a) in *Megalops* cyprinoids, Bishop and Odense (1966) in *Gadus morhua*, Mehrotra and Khanna (1969) in *Channa striatus*, Western (1969) in *Cottus gobio* and Shafi (1974) in *Channa batrachus*. *N. nandus* being the voracious feeder, requires rapid digestion of the food and thus gastric glands in this case are more compact.

In the present study, neck cells are not discernible. Similarly no neck cells could be seen by Kapoor (1953, 1957c), Mahadevan (1950), Ahsan-ul-Islam (1951), Pasha (1964a, b, c), Moitra and Ray (1979) in the gastric glands of fishes studied by them.

In the present study, the muscularis mucosa, although not so well formed can be easily distinguished as a layer of muscle fibres just outside the gastric glands. This indicates that this layer is present in the stomach of highly carnivorous species that take in large size prey and it serves to provide additional strength to the muscular wall of the stomach. Similar reports were also given by Mehrotra and Khanna, 1969 while studying the histomorphology of the stomach in *Muraenesox telabon* and *Channa striatus*.

The intestine of *N. nandus* is lined by columnar epithelium consisting of absorptive cells and the mucus-secreting cells. Similar observations were also made earlier by McVay and Khan (1940), Al-Hussaini (1946, 1947a and 1949a), Ahsan-ul-Islam (1951), Girgis (1952), Kapoor (1953, 1957a, b and c), Chaudhury and Khandelwal (1961).
columnar absorptive cells possess a stratified border at their apical end in all the species under report and this feature has also been noted by several earlier authors mentioned above. In *N. nandus*, the columnar cells far outnumber the goblet cells as reported by Tandon and Goswami (1968) in *Channa punctatus* and *Channa gachua*. The columnar cells are cylindrical in form with oval nuclei. The form of these cells, however, depends upon the maceration technique.

The intestinal villi show secondary folds of the mucous epithelium in the present study. This is specially pronounced in which the secondary villi fuse forming complex structures, thus increasing the absorptive surface. This may be due to highly carnivorous habit of the fish. Similar cases were also reported by Khanna and Mehrotra (1971) and Moitra and Ray (1977).

Histologically, the rectal folds in *N. nandus* are shorter and broader than in the intestine. The mucus secreting cells are better developed, more numerous and the muscularis is thicker. Similar observations have been made by Sarbah (1939), Al-Hussaini (1947, 1949a), Ahsan-ul-Islam (1951), Chaudhury and Khandelwal (1961) and Kapoor et al. (1975). Mucus secreting cells in the rectum are of goblet type which secretes large amount of mucus that lubricates the rectal contents and helps in defaecation. The presence of a few absorptive cells of the columnar type in this region indicates that some food is absorbed in this region also.

Histologically, hepatopancreas is similar to that of other carnivorous fishes. In the present study, pancreatic tissue is embedded in the hepatic cells. Similar observations were also made by Sarabohi (1939) in *L. rohita* and in *W. attu* by Kapoor (1953). Slipper (1946) classified the distribution of pancreas in teleosts into five types. The hepatopancreas is the principal digestive gland. Pancreatic tissue is present in a primitive diffused state and lies in a dispersed condition with the lobes of the hepatic tissue and
along the sites of the alimentary canal.

From the above discussion it is evident that the food and feeding habits of \textit{N. nandus} have produced histological modifications in the alimentary tract. The presence of the taste buds, the mucous cells in the buccopharynx; the enormous increase of mucous cells in the oesophagus; well developed tubular gastric glands in the stomach; the increase of goblet cells and the thick musculature in the rectum are all manifestations of the adaptive modifications of the alimentary canal of \textit{N. nandus} to its food.

5.1.7. Scanning Electron Microscopic studies of the alimentary canal

The study of detailed micro-histological structure of the alimentary canal of fishes was a constant endeavour in the field of topological study started in a few decades back for the better understanding of the different cell types in the mucosal lining of the alimentary canal concerned with digestion and absorption. Though there is an extensive information on the topological characteristics of the gut epithelium of different teleosts through Scanning Electron Microscope (Marsh and Swift, 1969; Sperry and Wassersug, 1976; Sis \textit{et al.}, 1979, Clarke and Witcomb, 1980; Ezeasor and Stokoe, 1980) but relatively little is known of the surface ultrastructure and mucosal modification of the digestive tract of Indian freshwater carnivorous teleosts, specially about the details of cellular organization observed by the use of SEM (Sinha, 1981, 1983; Sinha and Chakrabarti, 1985, 1986; Chakrabarti and Sinha, 1987; Chakrabarti and Ghosh, 1990; Chakrabarti \textit{et al.}, 1993.).

In the present study some detailed topological structure as revealed in an endangered carnivorous teleost, \textit{Nandus nandus} was recorded. \textit{N. nandus} is a bottom dwelling endangered carnivorous fish and inhabits in freshwater of this subcontinent particularly in the new alluvial zone. However, it is well established that the carnivorous forms have a
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relatively shorter gut than the herbivorous ones (Islam, 1951; Das and
Moitra, 1956; Kapoor, 1957; Khanna, 1961) as also observed in RLG
values (0.69-0.98). Therefore, the possession of a short gut as a
characteristic feature of a carnivorous teleost would seem to be same in
this fish also. On the other hand, morphoanatomical and histological
adaptations of the alimentary canal of the carnivorous fishes in relation to
their food and feeding habits have been studied by different authors
(Kapoor, 1953; Sarkar, 1959; Khanna, 1961; Tandon and Goswami,
1968). In the present study in N. nandus the shortness of the gut does
not necessarily reflect the functional surface area but only few studies
have been made on the gut of these fishes through the SEM (Sinha and
Chakrabarti, 1986; Chakrabarti and Sinha, 1987; Chakrabarti and Ghosh,
1990; Chakrabarti et al., 1993).

In the present study by SEM revealed that the buccopharyngeal
region in N. nandus is devoid of any prominent mucosal folds. This is due
to its carnivorous nature of diet which is comparatively larger in size and
normally requires more space for easy holding and transmitting the food
item. Further, the mucosa of buccopharynx is consisted of intimately
connected stratified epithelial cells provided with long straight microridges
arranged in a concentric whorl, leaving narrow depressions, similar type
of microridges in the buccopharynx have been reported in other
carnivorous teleosts (Sinha and Chakrabarti, 1986; Chakrabarti et al.,
1993). This type of microridges situated on the epithelial cells play a
major role for anchorage of thin mucus film over the soft mucous
membrane and this film is associated with lubrication of ingested food
from this region to short oesophagus. As carnivorous fish does not require
much mucin for gluing the ingested food, therefore, the occurrence of
microridges is simple to hold a small amount of mucin. On the other hand,
the presence of more complex nature of microridges and deep concavities
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in between microridges on the superficial cells of buccopharynx has been reported in herbivorous and omnivorous fish (Sinha, 1981, 1983; Sinha and Chakrabarti, 1985). The number of taste pores located in the buccopharyngeal region is also few and far between in _N. nandus_. This is probably due to the fact that the sight-feeding habit of the fish prevails while the gustatory organs are of secondary importance.

The well-developed mucosal folds in oesophageal region maintain a greater contractibility for increase in effectiveness to distention for communicating the food particles and also to withstand the trauma resulting from ingested material. The presence of broad microridges at the apical ends of the squamous epithelial cells constituting the outer layer of the mucosa is a characteristic feature of this region. The main function of microridges is to adhere the mucus secreted by the adjacent mucous cells in the furrows formed between them. In _N. nandus_, the concavities in between the microridges are comparatively broader and deeper than those of buccopharynx resulting in the retention of more amount of mucus for the lubrication of a carnivorous diet. However, similar functions of microridges have also been recorded in the oesophageal region of the trout (Sperry and Wassersug, 1976). Hughes (1979) on the other hand, described that mucus occupies the spaces between the microridges to form a flat interface in gill epithelial cells of teleosts. Sis et al., (1979) also reported the complex pattern of ridges in squamous epithelial cells of the oesophagus in channel cat fish. The labyrinth-patterned microridges in comparison to herbivorous fish is quite broader in _N. nandus_.

The complex nature of foldings in stomach wall in the fish under study not only increase the total mucosal surface but also retain ingested food for longer periods for effective functioning of stomach involved in carnivorous mode of feeding. However, the most striking feature of the luminal surface of the epithelial cells of stomach is the presence of short
and stubby microvilli justifying its poor or no role in absorption process. On the contrary, secretion of mucus by the epithelial cells which coating the microridges of the same may offer protective devices for preventing any chemical injury and autodigestion of the stomach wall.

The mucosal folds in the intestine in the present study also modify accordingly, resulting in the increase of mucosal surface. It is well established that primary functions of this region are absorption and secretion although partial retention of semidigested food, reaching from the stomach also occurs while the same passes through the zig-zag course of this region. The luminal surface of the entire intestine is lined with well-developed absorptive columnar epithelial cells. However, major feature of intestine is the scalping of the luminal plasma membrane of the columnar cells into microridges. These microridges probably serve the purpose of holding profuse quantity of mucin for easy transmission of semidigested food. A highly compact nature of microvilli on the columnar epithelial cells in the middle intestine is suggestive of their active participation in the absorption. The luminal end of the columnar cells of *N. nandus* also bears a zone of microvilli which are continuous with the respective microridges. The microvilli zone has been termed as a brush-boarder by Al-Hussaini (1947), Al-Hussaini and Kholy (1953), by studying a variety of teleost. These microridges may perform various functions including absorption. Sinha (1983) also reported similar microvilli zone in the intestine of *Labeo rohita*.

The increase in the surface area of the rectal mucosa is affected by the unique arrangement of mucosal folds as revealed by the present study. In the present observation, short and inconspicuous microridges in the apical surface of the columnar epithelial cells in this region elucidate its negative role in the absorption process. Microridges are often
associated with the heavy mucus deposition which helps in lubrication of undigested food materials for easy defaecation.

5.2. Physico-chemical Parameters

5.2.1. Temperature

Temperature is recognised as a major limiting factor because aquatic organisms have narrow tolerances. It is also regarded as one of the relevant parameters in water quality assessment and plays an important role in the metabolic activity of organism. The thermal properties of any water body are also unique. It is well known that atmospheric temperature is influenced directly by solar radiation. The relative position of the earth to the sun is perhaps the most important factor influencing the atmospheric temperature. In general, the surface water temperature fluctuations seem to follow those of the atmospheric temperature. The combined effects of air and water help to minimize the temperature changes, therefore, the range of variation is smaller and changes occur very slowly in water than in air. Welch (1948) opined that smaller the body of water, the more quicker the changes in the atmospheric temperature. Sugunan et al., (2000) reported that in shallow beels the whole water body gets heated up rapidly, thus increasing the spread of chemical and biochemical reactions. In the investigated beel the water temperature also changes with the atmospheric temperature.

Bhowmik (1988) reported that maximum and minimum temperature in beels and baors of West Bengal varied from 15.2 to 33.8°C. In this study, the water temperature ranged from a minimum of 22°C in January, 2002 up to a maximum of 34°C in April 2002 during the first year and from a minimum of 18.5°C in January 2003 up to a maximum of 34°C in May 2003 during the second year (Fig. 30). The environmental temperature was higher than the pond water temperature as recorded

Fig. 30: Monthly fluctuations of air and water temperature of Mogra beel

Seasonal fluctuations of water temperature revealed that minimum temperature was recorded during the winter season and maximum temperature was recorded during monsoon season followed by summer season. The high and low temperature is related to the atmospheric heat which is higher in summer and lower in winter. Fast microbial decomposition followed by release of energy could be one of the important reasons for increased temperature during rainy season. The values were within the prescribed limit of ISI (1982). These results are in conformity with the observations of Welch, 1948; Singh 1975; Hiware and Ugale, 2003; Bakthavathsalam et al., 2003; Bhaumik et al., 2004; Islam and Gyananath, 2002; Mishra and Tripathi, 2003; Sukumaran and Das, 2002; Baruah et al., 1998a and b.
5.2.2. pH

pH is a measure of the acid balance of a solution and is defined as the negative of the logarithm to the base 10 of the hydrogen ion concentration. The pH depends on the amount of calcium and magnesium, and carbon dioxide tension in the water. In unpolluted water pH is primarily controlled by the balance between carbon dioxide, carbonate and bicarbonate ions, as well as natural compounds such as humic and fulvic acids. The latter in turn is influenced by the photosynthetic activities of the aquatic vegetation and the life cycle in the pond. The pH of water is also influenced by geology of catchment area and buffering capacity of the water. At a given temperature, pH gives an indication of the acidic or alkaline nature of the water. It is controlled by the dissolved chemical compounds and the biochemical processes in the water.

pH of Mogra beel was found to be alkaline and ranged from 7.3 to 9.7 (Sugunan et al., 2000). The pH values recorded on the present study exhibited near neutral to alkaline trend (6.9 to 8.5) (Fig. 31). The present result of alkaline pH is in agreement with the study of Bhowmik (1988) where the pH values of the beels and baors of West Bengal was recorded between 6.8 and 9.1. Alkaline nature of water was also recorded by Baruah et al., (1998a & b), Mishra et al., (2003), Sunkad and Patil (2003), Dasgupta (1993), Hiware and Ugale (2003), Bakthavathesalam et al., (2003), Baligar and Chavadi (2004), Sharma et al., (2004), Bhaumik et al., (2004), Sarkar and Ray (2004) in various fresh water bodies. Slightly acidic to alkaline pH (6.8 to 9.1) was also recorded by Samanta and Das (2002).

In Mogra beel, pH values were maximum in winter months and minimum during monsoons which appears to be influenced by some of the climatological and vegetational factors as pointed out by Kant and 

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Kachroo (1975) while working on Kashmir lakes. Higher values of pH in the winter and lower during the monsoon season have also been reported earlier by Shanoo (1982), Bandopadhyay and Gopal (1990), Singh and Singh (1999), Biswas (2002), Hiware and Ugale (2003). The low pH value during the monsoon may be due to incoming rain water resulting in increase in turbidity of the water which in turn reduced the photosynthetic activity of algae leading to accumulation of carbon dioxide and reduction of pH (Adibisi, 1980). The alkaline nature was due to photosynthetic activity of plants which derive carbon dioxide from bicarbonates of calcium and magnesium, converting them into carbonates which were precipitated. Due to the increase in the concentration of carbonates the water becomes more alkaline (Dasgupta, 1993). A direct correlation between pH and carbonates has been reported by Jana (1971) and Nasar and Munshi (1974) from other places in India.

![Fig. 31: Monthly fluctuations of pH of Mogra beel](image)

Wetzel (1983) opined that the distribution of pH is strongly influenced by various biologically mediated reactions most conspicuous of which is the photosynthetic utilization of carbon dioxide in the
trophogenic zone, which tends to reduce carbon dioxide content and to increase pH. In addition to this, it may be noted that several factors may be responsible for the fluctuations of pH of water bodies which in turn may cause several other processes; smaller the pond, greater the process. Nevertheless, there is always a close relationship between pH, phytoplankton crop and photosynthetic activity (Sumitra, 1969). A slight alkaline level enhances the growth of phytoplankton and thereby more fish production (Santhanam et al., 1987).

In natural waters pH ranges from 6.5 to 8.5 (Warren, 1971). Hora and Pillay (1962) have shown that pH range of 7.0 to 8.0 was characteristic of good water suitable for fish culture. Fish cannot survive in pond water where pH values are less than 5 and greater than 11 (Alikunhi, 1957). He found that pH plays a vital role in the productivity and found the best range between 7.5 and 8.5. The results of pH analysis of Mogra beel (6.9 to 8.5) indicated that its pH was within the above range. It also followed the standards given as per ISI (1982). The range of pH recorded in the present study (6.9 to 8.5) is also in agreement with the study of Bhowmik (1988) where the pH value of the beels and baors of West Bengal was recorded between 6.8 and 9.1.

The pH of water of the present study had a positive relationship with alkalinity and negative relationship with free carbon dioxide as revealed by the correlation coefficient (r) (Annexure C).

5.2.3. Transparency

The transparency (Secchi disc transparency) of a water body is often the only tool available to fish farmers for maintaining water quality. The penetration of light is often limited by suspended materials, turbidity, especially when caused by clay and silt particles, is often important as a limiting factor. The transparency of water in turn governs the population of aquatic organisms of the water body.
According to Sugunan et al., (2000) transparency of Mogra beel ranged between 34 and 150 cm. The value of transparency in the present study fluctuated from 42.0 cm to 150.0 cm during the first year and from 28.12 cm to 161.0 cm during the second year (Fig. 32). Similarly Ahmed and Sarkar (1997) showed that transparency varied from 48.0 to 140.0 cm in Umrang reservoir of Meghalaya. Transparency showed irregular and monthly fluctuations. Transparency was found to be maximum during winter and minimum during monsoon. Similar result was obtained by Singh and Singh (1999) from Maidhiya pond of Birganj in Nepal. Hazarika and Dutta (1997) reported low transparency values during monsoons in Tasek Lake (Meghalaya) which coincided with the observations by Jhingran et al., (1964), Kant and Anand (1968). Ansari (1986) reported that low transparency in rainy season results the food scarcity due to the blocking of light penetration. The lowest transparency during rainy season was due to pouring of large amounts of soil particles and suspended organic matter brought in through surface run off (Sukumaran and Das, 2002). According to Hazarika (1997), low transparency was caused by allochthonous turbidity caused due to rain in the freshwater ponds of Dighali Pukhuri and Ulubari fish pond of Guwahati, Assam. This may be true in the present study also.
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Fig. 32: Monthly fluctuations of transparency of Mogra beel

Water transparency after monsoon showed sharp increase due to quick settling of suspended particles (Kaushal et al., 1995). According to Mishra et al., (2003) low water temperature reduces phytoplankton production thus causing high transparency values. At high temperature transparency was minimum during the peak period of plankton production.

Berner (1951) and Bose (1956) found turbidity as the most important factor governing the distribution of fish as it directly influenced the plankton productivity. There were wide seasonal fluctuations in the transparency of the different water bodies (Khan and Siddique, 1974; Singh, 1977; Singh et al., 1987).

In the present study transparency was found to have negative relationship with water temperature as indicated by r-value (Annexure C).

Fish pond managers often use the technique to adjust the level of fertilizer to produce a good but not too great a growth of phytoplankton.
5.2.4. Dissolved Oxygen (DO)

Maintenance and distribution of biota in aquatic ecosystem to a great extent depend upon the concentration of dissolved oxygen. Oxygen is an A-1 limiting factor, especially in lakes/ponds and in water with a heavy load of organic material. The solubility and specially the dynamics of oxygen distribution in ponds and lakes are basic to the understanding of the distribution, behaviour and growth of aquatic organisms. The rates of supply of dissolved oxygen from the atmosphere through air saturation and from the aquatic plants through their photosynthetic activity and hydro-mechanical distribution of oxygen are counter balanced by consumptive metabolism. A daily production of 8g/m² and excess production by over respiration would indicate a healthy condition for the ecosystem. The concentration of oxygen in water also depends upon temperature, pressure, and concentrations of various ions (Wetzel, 1975). Although plants and animals consume large amounts of dissolved oxygen the major consumption of the same is associated with bacterial decomposition of organic matter (Wetzel, 1983). Depletion of oxygen means more oxygen consumption (respiration) than oxygen production. Oxygen production can be a basis for determining productivity.

Sugunan et al., 2000, found dissolved oxygen of Mogra beel to range from 6.4 to 22.1 mg/l while studying the ecology and fisheries of West Bengal beels. The dissolved oxygen in the present study was observed to range between 1.56 mg/l to 10.06 mg/l in the first year and from 2.92 mg/l to 9.7 mg/l in the second year (Fig. 33). Similar to the present study, Dasgupta (1993) found DO to range from 1.0 to 10.3 mg/l in a hostel pond of Imphal in Manipur. Singh and Singh (1999) found DO to vary from 2.4 to 8.5 ppm from Maidhiya pond of Birganj in Nepal. Sultan et al., (2003) found dissolved oxygen to range between 1.8 to 9.2 mg/l in Paheenj reservoir at Jhansi, U.P.
Fig. 33: Monthly fluctuations of dissolved oxygen of Mogra beel

Seasonal studies of DO showed minimum value during the monsoon period and maximum amount during winter. Hutchinson (1957), reported higher amount of DO content in the winter season and lower in the summer due to the greater capacity of water to hold more DO at low temperature. High DO value during winter season and minimum DO during rainy season was also reported by Mishra et al., (2003); Mishra and Tripathi, (2003); Sukumaran and Das, (2002); Chourasia and Adoni, (1985); Kala and Sharma, (2002). According to Singh and Singh (1999), water temperature influences the oxygen content of Maidhiya pond of Birganj in Nepal. He found high values of DO during low temperature period as also observed earlier by Singh and Sahai, 1979; Unni, 1982; Chitranshi, 1987; Jindal and Vasisht, 1985. Sukumaran and Das, 2002 reported that lower DO content in summer was due to lesser solubility of oxygen in water at higher temperature. The lower catabolic activity of the aquatic organisms probably accelerated the high oxygen level in the water.
The fluctuations in DO values indicate the inverse relationship between temperature and dissolved oxygen and due to the effect of photosynthesis by phytoplankton (Mishra et al., 2003). Temperature and dissolved salts greatly affect the ability of water to hold oxygen. The solubility of oxygen is increased by low temperature and decreased by high salinity. According to law of solubility of gases periods of high temperature should be periods of low oxygen content and vice-versa. Reid (1961) stated that solubility of oxygen in water was known to be affected inversely by the rise in temperature (Ohle, 1952; Mortimer, 1956; Wetzel, 1983; Moss, 1988; Hazarika, 1997) which has been supported by the present findings in the water of Mogra beel. Dasgupta (1993) reported that the oxygen content was also considerably affected by the metabolic activities of the biotic community. According to him, the low concentration of oxygen was partly due to the photosynthetic activity. Similarly high values of oxygen may be related to vigorous photosynthetic activities of different species of algae and littoral flora. DO is also affected by the respiratory activities of the organisms of the pond and by the oxygen consuming activity of the decaying organic matter at the bottom of the ponds. Thus, the higher DO content in the study site was due to higher autotrophic activity and low organic and inorganic load and low DO content was due to high organic and inorganic load. This agrees with the report of Kumar et al., (1991), Singh and Pandey (1991), Sharma et al., (1992). The present study also indicated that the chief controlling factor of oxygen content in the pond was not only the physical factor of solubility (temperature). This supported the findings of Ganapati (1940) and Odum (1978). According to Odum (1978), when weed and phytoplankton are abundant the DO in the water undergoes wide fluctuation, sometimes even reaching very low limits. Oxygen consuming activity of the decaying organic matter with high oxygen demand may be responsible for poor oxygen content. Chattwal (1989) noted that the DO
concentration at the minimum 5.0 mg/l is necessary for fish survival and proper growth. DO ranging between 5.0 and 10.0 ppm might be considered favourable for fish ponds. Lower oxygen content was definitely detrimental to fishes, while high DO content was also not conducive since it indicates algal bloom in the pond (Nath et al., 1994).

In the present study dissolved oxygen was found to have inverse relationship with water temperature and free carbon dioxide. Oxygen production can be a basis for determining productivity. It is also recorded that the oxygen and carbon dioxide behave reciprocally.

5.2.5. Alkalinity

Alkalinity refers to the total concentration of carbonates and bicarbonates in water. The chemical processes along with dissociation of carbon dioxide determine the acidity and alkalinity of water body. Acidity and alkalinity of water is determined by the abundance or, more correctly, the activity of $\text{H}^+$ ions. Higher concentrations of $\text{H}^+$ ions make water more acidic while lower concentrations make it more alkaline. It was considered to be an index of aquatic productivity (Moyle, 1946 and Swingle, 1957).

Alkalinity of Mogra beel was reported to range between 50 and 128 ppm (Sugunan et al., 2000). The total alkalinity in the Mogra beel in the present study varied from 20.0 to 31.20 ppm in the first year and from 8.0 to 21.2 ppm in the second year (Fig. 34). The seasonal trend was found to be almost identical. Naturally alkalinity in the tune of 40 ppm is considered more productive than low alkalinity (Moyle, 1945, Mair, 1966). Alikunhi et al., (1955) pointed out that alkalinity of highly productive waters must be above 100 ppm. Moyle (1946) categorized the productivity of water bodies on the basis of alkalinity into three groups: low (below 20 ppm), moderate (20 to 40 ppm) and medium to high (40 to 50 ppm). Philipose (1960) grouped the static water on the basis of total
alkalinity as low (4 to 50 ppm), moderately high (50 to 100 ppm) and fairly high (100 to 120 ppm). Nath et al., (1994) opined that 80-150 ppm alkalinity appeared to be optimum for semi-intensive culture ponds. Ponds with low alkalinity were poorly productive and with high alkalinity were medium productive. Saha et al., (1971) reported alkaline water above 120 ppm as alkalitrophic.

Fig. 34: Monthly fluctuations of bicarbonate alkalinity in Mogra beel

Baruah et al., (1998, a) recorded low alkalinity values in urban area (Guwahati city). Low to moderate alkalinity values were also recorded again by Baruah et al., (1998, b) and indicated that the lower value of alkalinity was due to low concentrations of carbonates, bicarbonates which is true in the present case also. Ahmed and Sarkar (1997) also detected low levels of alkalinity which were much below the level prescribed for the productive range. Similar low values of alkalinity were observed in Kyrdemkulai reservoir in Meghalaya by Sugunan and Yadava (1991). Low values of alkalinity were further recorded by Sunkad and Patil (2003) in Rakasakoppa reservoir of Belgaum, Karnataka and Kaushal et al., (1995) in Baira reservoir, Himachal Pradesh. Hazarika (1997)
DISCUSSION

recorded a very low alkalinity (9.0 to 16.5 mg/l) in Tasek lake of Meghalaya which is in consonance with the findings of Sharma (1995).

Alkalinity is controlled by the sum of titratable bases principally carbonate, bicarbonate and hydroxides. Carbonates and bicarbonates are inversely related. Carbon dioxide is derived from bicarbonates by converting the bicarbonates into carbonates. With the increase of carbonates in water bicarbonates decrease and vice-versa. Carbonate alkalinity was never detected from Mogra beel. Dasgupta (1993) also could not detect carbonate from Rashmandal pond at Imphal in Manipur. In contrast, in Mogra beel the alkalinity was found to be due to bicarbonate only. The effect of rainfall in decreasing the bicarbonates is well known in fresh waters (Michael 1969). This seems to be true in the present study too.

5.2.6. Free Carbon dioxide

According to Munawar (1970) carbon dioxide appears to be an important component of buffer system of water. This gas influences the concentration of carbonates and bicarbonates in water. The quantity of free carbon dioxide depends on the quantity of water or on the quantity of gas in the atmosphere. Carbon dioxide dissolves readily in water. It is thirty times more soluble than the oxygen. Carbon dioxide is highly soluble, more at lower temperatures and at higher pressures also.

In Mogra beel free carbon dioxide was detected during the entire study period. The carbon dioxide content fluctuated from 4.23 to 62.0 mg/l in the first year and from 3.0 to 96.0 mg/l during the second year (Fig. 35). Its highest value was recorded in the monsoon months and lowest value was registered during winter. This might be due to increased and decreased biological activities of aquatic fauna and flora.
Fig. 35: Monthly fluctuations of free carbon dioxide of Mogra beel

Dasgupta (1993) detected high values of free carbon dioxide (14.5 to 72.45 mg/l) in Rashmandal pond at Imphal in Manipur. He stated that it was due to the presence of great amounts of decaying organic matter in the bottom layers. Due to the presence of excessive vegetation great amounts of carbon dioxide would have been released in the water during respiration. Besides, during low photosynthetic periods the carbon dioxide increased due to the lower uptake of carbon dioxide by plants (Dasgupta, 1993). High values of carbon dioxide in all the months of the year was also detected by Hazarika (1997) in Dighali Pukhuri of Assam which may be apparently due to the decomposition of hydrophytes as also reported by Allegeir et al., (1932). The high concentration of carbon dioxide might also be due to less photosynthetic activity because of low phytoplankton population and more respiratory activity of zooplankton and other aquatic animal fauna (Hiware and Ugale, 2003). Higher concentration of free
carbon dioxide also indicates the lower concentration of autotrophs leading to less utilization of carbon dioxide. The relation between carbon dioxide and autotrophs was also noted by Baruah et al., (1996).

Oxidation of organic material with the rise of temperature adds more carbon dioxide to the water (Seenayya, 1971). This may be true in the present study also. Besides, increase in free carbon dioxide values in Mogra beel during rainy season was caused due to the formation of carbonic acid after the reaction.

\[ \text{CO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3 \rightleftharpoons \text{H}^+ + \text{HCO}_3^- \]

and release of more \( \text{H}^+ \) ion to the beel water to exhibit an inverse relation with pH. A more or less similar trend has been reported from fresh water bodies of India by Rao (1955), Zafar (1964) and Swarup and Singh (1979). Low free carbon dioxide recorded during winter months may be attributed to phytoplankton assimilation through photosynthesis (Talling, 1976).

5.2.7. Chemical Oxygen Demand (COD)

COD level is important to evaluate the water quality with respect to the presence of organic content in terms of biodegradable and non-biodegradable compounds. The COD will always be higher than the BOD as the former includes substances that are chemically oxidized as well as biologically oxidized. COD is measured in terms of quantity of oxygen required for oxidation of organic matter to produce carbon dioxide and water. It is a measure of organic matter in the sample including biodegradable fraction and fraction which survives bacterial attack and is also a strong chemical oxidant. In the present findings the COD values varied between 5.0 mg/l to 100.0 mg/l in the first year and from 9.0 mg/l to 62.0 mg/l in the second year (Fig. 36). COD value was found to increase in the monsoon months which were similar to the findings of Islam and Gyananath (2002), Mishra and Tripathi (2003). The increase in
COD values in the monsoon months was probably due to the transport of surface impurities in the water and it was found to decrease with decreasing water table of ground water.

Fig. 36: Monthly fluctuations of chemical oxygen demand of Mogra beel

5.2.8. Organic carbon

The influence of dissolved organic carbon (DOC) on freshwater planktonic food webs has received renewed attention in recent years (Hessen, 1992 and Jones, 1992) which also acts as nutrient. Several investigators have shown that both dissolved and particulate detritus organic carbon comprise a large reservoir of energy that stabilizes aquatic ecosystems and fuels to lake metabolic processes. The bulk of plankton community respiration in oligotrophic lakes probably corresponds to bacterial use of both autochthonous and allochthonous DOC (Jones, 1992; del Giorgio and Peters, 1994). In the present findings the organic carbon varied between 0.9 mg/l and 4.5 mg/l in the first year and 2.1
mg/l and 5.7 mg/l in the second year (Fig. 37). It was highest during summer months and lowest during monsoon months. Datta (1999) found concentration of organic carbon to vary between 0.12 and 0.55 mg/l of surface and bottom water.

![Graph showing monthly fluctuations of organic carbon of Mogra beel](image)

**Fig. 37: Monthly fluctuations of organic carbon of Mogra beel**

5.2.9. Phosphate-phosphorus (PO$_4$ – P)

Phosphorus is an essential micronutrient and critical abiotic factor which was known to limit the productivity of fresh waters (Wetzel, 1983). Of different compounds of phosphorus, phosphate is the only form directly utilised by primary producers. It is extremely reactive and interacts with many cations (e.g., iron and calcium).

The phosphate concentration in the present investigated site ranged between 0.09 and 0.28 ppm during the first year and 0.075 and 0.18 ppm during the second year (Fig. 38). According to Sugunan et al., 2000, phosphate level of Mogra beel ranged from trace amounts to 0.02 mg/l. The supply of phosphorus in the pond appears to be dependent upon drainage and rain. In this beel, however, the supply of inorganic
phosphorus for biological activity seems to be very low in comparison to the values reported for other fresh waters of India. Sreenivasan et al., (1964) found very low concentrations of phosphorus from 0.4 to 0.8g atom/l in Bhavanisagar reservoir in Madras state while George (1962) reported a range of 0.04 to 0.25 ppm in a fresh pond at Delhi. Khan and Siddique (1974) recorded phosphate concentration ranging from 0.157 to 0.5409g atom/l in a perennial fish pond at Aligarh.

![Graph showing monthly fluctuations of phosphate-phosphorus of Mogra beel]

**Fig. 38: Monthly Fluctuations of phosphate-phosphorus of Mogra beel**

Phosphate content showed seasonal variations in Mogra beel. Maximum phosphate concentration was recorded during monsoon months and minimum phosphate concentration was found in summer months. The maximum value of phosphates in the monsoons was due to rainfall which added atmospheric salts to the river water as also reported by Das and Srivastava (1956), Michael (1969) and Lahon (1983), Sunkad and Patil (2003), Kala and Sharma (2002), Karthikeyani et al., (2002), Islam and Gyananath (2002), Singh and Singh (1999), Mandal (1979) in a fresh water fish pond at Burdwan, Biswas (2002).
Phosphate content showed positive relationship with COD and negative relationship with DO as revealed by r-values (Annexure C).

5.2.10. Nitrate-nitrogen (NO$_3$ – N)

Nitrate-nitrogen is the end product of nitrification process and it is the most stable nitrogenous nutrient. It represents common inorganic form of nitrogen which serves or yet another micronutrient for autotrophs and is also known to limit their production under certain condition (Wetzel, 1983).

Nitrate concentration in Mogra beel ranged from 0.1 to 0.42 ppm in the first year and from 0.08 to 0.5 ppm in the second year (Fig. 39).

![Nitrate Nitrogen Concentration](image)

Fig. 39: Monthly fluctuations of nitrate-nitrogen of Mogra beel

Nitrate content of Mogra beel ranged between 0.33 and 1.57 mg/l (Sugunan et al., 2000). Nitrate content of Mogra beel in the present study also showed distinct seasonal fluctuations. The concentration of nitrate was maximum in winter and minimum in summer months. The gradual increase in nitrate content in winter months could be due to the inflow with rain water. An identical trend was also reported by Gonzalves and
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Joshi 1946; Môitra and Bhowmick 1968; Goswami, 1985; Yadava, 1987; Hazarika, 1997. A wide range of variations in the concentration of nitrate in fresh waters has been reported by several workers. Upadhayaya (1964) reported a concentration of 0.09 to 3.5 ppm of nitrate in many fresh waters of Uttar Pradesh. Nitrate-nitrogen being a stable product accumulates in the pond as a result of inputs like feed and fertilizers, plankton die off and metabolites.

5.3. Biological Parameters

5.3.1. Plankton community

Results of plankton analysis of Mogra beel during two-year period showed that phytoplankton was dominating over zooplankton in both the years. Fluctuations of plankton in different season are the reason of interaction between abiotic and biotic factors, fertility of water and consumption as food by fishes. The population of fish stock is directly related to qualitative and quantitative abundance of plankton population (Arivazhagan and Kamalaveni, 1997). This was also reported earlier by Singh (1992).

Moderately low plankton population in the present site can be attributed to some extent to the low alkaline water and this is in accordance with Jana (1978) and Islam (1990), who generalized that waters with high alkalinity show a great productivity. Such relationship between alkalinity and plankton abundance was observed earlier by many workers (Vasisht, 1968; Olsan and Sommerfeld, 1977 and Alam, 1980).

Negative correlation was found between plankton abundance and alkalinity \( (r = -0.264) \) (Annexure D). Temperature is considered to be most important factor for determining the fluctuation in plankton. Byars (1960) has stated that temperature is the determining factor in seasonal distribution in organism. Golterman (1972) has stated that an increase in
DISCUSSION

Temperature may affect the net growth of phytoplankton negatively or positively, depending on the type of species. However, Jana (1979) and Bose and Garai (1993) could not establish any significant correlation between phytoplankton and temperature. In the present case, the low temperature (Fig. 40) would have influenced the production of plankton in the beel. Mandal (1976) also collected abundant of phytoplankton during winter. In the present site plankton and both air and water temperatures showed negative correlation (-0.179 and -0.190) (Annexure D).

pH values of the present site was positively related with plankton density, however the effect was not so pronounced ($r = 0.370$) (Annexure D).

Fig. 40: Monthly fluctuations of plankton community of Mogra beel

Secchi disc transparency and light penetrability of water seems to affect the plankton production and seems to be a good index of plankton production. The water of the present site was clear almost through the year and due to this there was abundant plankton production. Positive correlation was found between plankton abundance and transparency ($r$...
The DO content showed a positive relationship with plankton, as it was high in the winter when plankton had its peak. On the other hand, the minimum oxygen coincided with low plankton concentrations in monsoon months. r-value was found to be 0.189 (Annexure D).

The role of nutrients in aquatic ecosystem for plankton abundance is well known. However, no direct relationship could be made out between the quality and quantity of plankton abundance of individual species and the nutrient level probably due to multiple factors operating in the complex biological system. The present investigation is in accordance with earlier findings of Kala and Sharma (2002), Sukumaran and Das (2002) and Hazarika (1997).

5.4. Sediment

The biological productivity of any water body is influenced by the quality of the bottom soil. The bottom soil composition of a water body is the resultant contribution of various factors and for this reason great variation exists. The chemical characteristics of the bottom soil of Mogra beel are given in Table 26.

The soil pH was mostly alkaline in reaction and ranged from 6.9 to 7.98. The deposition of decaying weeds at bottom contributed to the richness of the soil. It was found that organic carbon content of the soil of Mogra beel ranged from 1.07 to 2.20%, available nitrogen ranged between 0.14 and 1.96%, available phosphorus ranged between 0.005 and 0.039% and available potassium ranged from 1.6 to 6.15%. Sugunan et al. (2000) studied the beels of West Bengal and reported that soil pH ranged from 6.7 to 7.8, which was considered to be the ideal range for good fish production. Sinha et al. (1973) studied a fish culture pond of Kalyani (W.B.) and reported that the soil pH ranged from 7.4 to 7.5 and
organic carbon content of soil ranged from 0.774 to 1.62%.

Nutrient contents of the bottom soil of lake Badkhal in Haryana were estimated by Kaushal and Sharma (2001). They reported that the soil organic carbon was moderate but available nitrogen and available phosphorus contents varied from low to medium range. Rai (1994) studied some soil parameters of six non-drainable sewage-fed ponds for a period of six years and reported an increase in the level of organic carbon and phosphorus and a marginal increase in available nitrogen indicating a low rate of mineralisation with decline in productivity. Paria and Konar (2000) studied a pond ecosystem in Jalpaiguri district and observed that available nitrogen and available phosphorus of soil took part in controlling the pond environmental conditions. Mahajan and Mandloi (1998) studied Adhartal pond (MP) and recorded the availability of soil nutrients like available nitrogen, phosphorus and potassium which were found to be higher during monsoon. Agarwal et al., (1993) studied Sagar Lake (MP) and stated that the concentration of total nitrogen was maximum in pre-monsoon while the total phosphorus was maximum in monsoon. Purushotham (1985) stated that increase in water levels caused to enhance the nitrogen content of the sediment during rainy season. The nutrient parameters of Mogra beel did not show marked variations during different seasons.

It has been observed that soil with organic carbon 1.5 to 2.5 or above, is usually productive in nature (Banerjee, 1967 and Moyle, 1946). The potentiality of the soil of Mogra beel in this context is usually productive.
5.5. Relationship between Physico-chemical Parameters of the Water and Biology of the Fish

5.5.1. Gonado-somatic Index (GnSI) and water temperature

The graph (Fig. 41) was prepared with GnSI and water temperature on the y-axis and the months of study on the x-axis.

Range of water temperature during the spawning season was 32-34°C in the first year and 31.5-34°C in the second year.

Gonado-somatic index ranged from 2.20-4.62 in the first year and 2.69-4.78 in the second year during the breeding season.

During the spawning season the temperature was high. GnSI was also higher than other periods. It was observed that during the breeding season there was a relationship between these two parameters because peaks of these two parameters were observed during this period. GnSI was higher due to the development of gonads during the breeding season.

Positive correlation ($r = 0.49$) was found between these two...
5.5.2. Gonado-somatic Index (GnSI) and pH

The graphical presentation (Fig. 42) was made with GnSI and pH on the y-axis and the months of study on the x-axis.

Fig. 42: Relationship between Gonado-somatic index and pH during two-year study period

No definite relationship could be established between the two parameters from the graph.

During the breeding season (April-June) the pH value was found to be 6.9 (constant) in the first year and it ranged from 7.1 - 8.1 in the second year. Average pH value during the breeding season was 6.9 for the first year and 7.5 for the second year.

Negative relationship ($r = -0.36$) was obtained between GnSI and pH in Mogra beel (Annexure E).

5.5.3. Gonado-somatic Index (GnSI) and Dissolved Oxygen (DO)

The graph (Fig. 43) was prepared with GnSI and Dissolved Oxygen on the y-axis and the months of study on the x-axis.
Fig. 43: Relationship between Gonado-somatic index and dissolved oxygen during two-year study period

No definite relationship could be established between the two parameters from the graph.

During the breeding season the DO ranged from 2-4.3 mg/l in the first year and from 6.0-7.8 mg/l in the second year.

Average DO value during the breeding season was 3.3 mg/l for the first year and 6.64 mg/l for the second year.

Negative relationship (r = 0.29) was obtained between GnSI and DO in Mogra beel (Annexure E).

5.5.4. Gastro-somatic Index (GSI) and water temperature

The graph (Fig. 44) was prepared with gastro-somatic index and water temperature on the y-axis and the months of study on the x-axis.
Fig. 44: Relationship between Gastro-somatic index and water temperature during two-year study period

No definite relationship could be established between the two parameters from the graph.

Analysis of correlation coefficient (r) revealed positive relationship between the two parameters (r = 0.17) (Annexure E).

5.5.5. Gastro-somatic Index (GSI) and Plankton abundance

This representation (Fig. 45) was prepared with gastro-somatic index and plankton abundance on the y-axis and the months of study on the x-axis.

No definite relationship could be concluded between the two parameters from the graph. This might be due to the fact that the fish *Nandus nandus* is not a plankton feeder. Plankton is important for other aquatic species on which *N. nandus* feeds.
Fig. 45: Relationship between Gastro-somatic index and plankton abundance during two-year study period

Analysis of correlation coefficient (r) showed negative relationship (r = -0.04) between the two parameters (Annexure E).

5.5.6. Condition factor (K) and Plankton abundance

The graph (Fig. 46) was prepared with condition factor and plankton abundance on the y-axis and the months of study on the x-axis.

From the graph it was found that condition factor increased from August and reached the peak during October and thereafter it decreased in the first year. Plankton abundance also showed similar trend and reached the peak during October in the first year. In the second year also both the parameters were found to be maximum during January.

From the graph it was evident that fluctuations in condition factor of the fish followed a similar trend with plankton abundance.

Although the fish did not feed on the plankton directly the condition of the fish depends indirectly on the abundance of plankton; since the food organisms of *N. nandus* depended on the plankton as their food.
Positive relationship \((r = 0.64)\) was found between the two parameters (Annexure E).

![Graph showing relationship between K Factor and Plankton abundance](image)

Fig. 46: Relationship between condition factor and plankton abundance during two-year study period

5.6. Relationship between Physico-chemical Parameters of the Water and Atmospheric Condition

The meteorological data during first and second years of study is shown in Table 27a and b.

5.6.1. Rainfall and Dissolved Oxygen (DO)

The graph (Fig. 47) was prepared with rainfall and DO on the y-axis and the months of study on the x-axis.

No definite relationship could be made out between the two parameters from the graph.

Analysis of correlation coefficient \((r)\) revealed a negative relationship \((r = -0.36)\) between the two parameters (Annexure E).
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5.6.2. Rainfall and transparency

The representation (Fig. 48) was prepared with rainfall and water transparency on the y-axis and the months of study on the x-axis.

Fig. 47: Relationship between rainfall and dissolved oxygen during two-year study period

Fig. 48: Relationship between rainfall and transparency during two-year study period
No definite relationship could be made out between the two parameters form the graph.

Analysis of correlation coefficient (r) showed a negative relationship (r = - 0.26) between the two parameters (Annexure E).

5.7. Relationship among Different Physico-chemical Parameters of Water

5.7.1. Plankton abundance and transparency

The graph (Fig. 49) was prepared with plankton abundance and water transparency on the y-axis and the months of study on the x-axis.

![Graph showing plankton abundance and transparency](image_url)

**Fig. 49:** Relationship between plankton abundance and transparency during two-year study period

No definite relationship could be made out between the two parameters form the graph.

Negative relationship (r = - 0.23) was obtained between the two parameters from the analysis of correlation coefficient (r) (Annexure D).

5.7.2. Air temperature and water temperature

The graphical figure (Fig. 30) was prepared with air temperature and
water temperature on the y-axis and the months of study on the x-axis.

From the graph it was found that fluctuations of air and water temperature followed a similar trend. Both the temperatures were minimum during the winter months and maximum during the monsoon months in two years study period.

Analysis of correlation coefficient (r) showed positive relationship (r = 0.93) between the two parameters (Annexure E).

5.7.3. Air temperature and Dissolved Oxygen (DO)

The graph (Fig. 50) was prepared with air temperature and water temperature on the y-axis and the months of study on the x-axis.

From the graph it was found out that air temperature and DO followed reverse trend.

DO was found to be low at higher temperatures and high at lower temperatures.

Analysis of correlation coefficient (r) showed negative relationship (r = -0.19) between the two parameters (Annexure E).

Fig. 50: Relationship between air temperature and dissolved oxygen during two-year study period