V. DISCUSSION

5.1. Food and feeding habits

The qualitative and quantitative analysis of food of *Priacanthus hamrur* indicated that this species feeds mainly on shrimps, crustacean remains and fish juveniles. Teleosts, juveniles of squids, crab, cuttlefish and octopus were of next importance in the stomach contents. These findings show that *Priacanthus hamrur* is a carnivorous fish feeding on free-swimming organisms near to the bottom. The absence of sand grains, detritus, benthic organisms in stomach of *Priacanthus hamrur* indicated that they do not browse at the sea bottom for food. Similar observations were made by earlier workers Rao (1967; Lester, 1968; Chomjurai, 1970; Wetchagarun, 1971; Rao, 1984; Ambak et al, 1987; Naik, 1990; Premalatha, 1997; Philip, 1998; Tessy and Inasu, 2003).

The percentage occurrence of shrimps in the gut contents of both the sexes were found to be varying in different months. During September 2005-May 2006, the highest percentage of shrimps was found in September in both the sexes, whereas during September, 2006-May, 2007, the highest percentage was seen in October in male and in the month of September, in case of female. The lowest quantity of shrimps was noticed in the month of May in both the sexes during September, 2005-May, 2006. During September, 2006 to May, 2007, the lowest in male was in May, while in female, it was in March and May. These monthly variations may be due to the factors such as relative abundance of shrimps, its consumption rate and age of fish. The high percentage of shrimps in the months of September and October may be due to their abundance in the environment after south west monsoon. Zacharia *et al.*, (1991) made similar observations on the food and feeding habits of *Priacanthus hamrur* in Mangalore waters. They observed less feeding activity
during May and based on the gut content analysis they indicated that this fish is highly carnivorous in nature.

Semi-digested matter was found to be next in abundance among the food items. It also occurred in all the months with considerable variations. During September, 2005 - May, 2006, the highest percentage of semi-digested matter was found in November for both the sexes, whereas during September, 2006 – May, 2007, the highest percentage was noticed in male during November and in April for female. The lowest quantity of semi-digested matter was observed in the month of February in both the sexes during September, 2005-May, 2006. During September, 2006-May, 2007, the lowest in male was in February, while in female, it was in September. The bulk of the semi-digested matter was mainly constituted by shrimps, crustacean remains and other food organisms. Philip (1994, 1998) reported the food and feeding habits of Priacanthus hamrur from upper-east coast of India and encountered the semi-digested matter comprised of more than 50% of stomach contents.

Crustacean remains were another main food item, which occurred in all the months with considerable variations. During September, 2005-May, 2006, the maximum percentage of crustacean remains was found in April in both the sexes, whereas during September, 2006-May, 2007, the highest percentage was noticed in April for male and in May for female. The lowest quantity of crustacean remains was noticed in the month of March in male and in December in case of female during September, 2006 to May, 2007. During September, 2006 to May, 2007, the lowest value in male was in September, while in female it was in December. The crustacean remains mainly included appendages, shells and other parts of crabs and shrimps.

The percentage occurrence of fish juveniles in the gut contents of both the sexes varied considerably in different months. During September, 2005 to May, 2006 the highest percentage of fish juveniles was found in January in both the sexes, in the subsequent year the highest percentage was recorded in the month of January. The lowest quantity of fish juveniles was recorded in the
month of April in male and in case of female it was September (period of September, 2005 to May, 2006).

During, September, 2006 to May 2007, the lowest in male was in April, while in female, it was in September.

Teleosts formed another important group of food items, comprising of those which were slightly larger in size and they have been identified. Of these, flat-heads, flatfishes, *Saurida* spp., *Stolephorus* spp., *Leiognathus* spp. and *Nemipterus* spp. were dominant. The percentage occurrence of teleosts in the gut contents in both the sexes varied considerably in different months. During September, 2005 – May, 2006 and September, 2006 – May, 2007 the highest percentage of teleosts was found in April in both the sexes. The lowest quantity of teleosts was observed in the month of October in both the sexes during September, 2005-May, 2006. During September, 2006- May, 2007, the lowest in male was in January, while in female, it was in December.

Other food items like juveniles of squid, octopus, crab, cuttle fish were also recorded in lesser quantities. Zacharia *et al.* (1991) studied the food and feeding habits of *Priacanthus hamrur* from Mangalore waters and reported that this species fed mainly on squids, lizardfish and *Therapon* spp. The food and feeding habits of *Priacanthus hamrur* along the Indian coast was revealed by Shivakami (2001), According to the author, this species feeds on pelagic crustaceans followed by fishes and smaller molluscs. Among crustaceans, euphausids were the most preferred food item followed by crabs (megalopa larvae of brachyurian crab, *Porcellanid* spp., *Portunus* spp.), penaeid shrimps and stomatopods (squilla and alima larvae). Fishes were represented by a variety of species such as *Stolephorus* spp., silverbellies, *Saurida* spp., flatfishes and flatheads were the next preferred group. Molluscan food items were dominated by juveniles of squids, cuttlefish, *Octopus* spp. and also smaller gastropod shells.

Overall analysis revealed that, in all the size groups starting from 14-15 cm to 33-34 cm, food items such as shrimps, semi-digested matter, crustacean remains, fish juveniles, teleosts, juveniles of squids, octopus juveniles, crab
juveniles and cuttlefish juveniles were found in different proportions. During September, 2005- May, 2006 shrimps were the most dominant in all the size groups, although they occurred in different proportions. In both the sexes, highest percentage was recorded in the size group 30-31 cm and lowest percentage in the size group 15-16 cm. During September, 2006- May, 2007, in male, highest percentage was recorded in the size group 31-32 cm and lowest percentage in the size group 14-15 cm. In case of female, the highest percentage was in the size group 30-31 cm and the lowest quantity was recorded in the size group 14-15 cm. Female showed more affinity towards shrimps than the male and larger size group (20-33 cm) showed higher percentage of shrimps compared to smaller size groups (15-21 cm). Tessy and Inasu (1991, 2003) reported on the food and feeding habits of *Priacanthus hamrur* from Kerala coast. They stated that in general the crustaceans (prawn and prawn tissues) were found to be the most favourable food items; however, the differences were noticed among the sexes and size groups of *Priacanthus hamrur* with respect to the consumption of prawns. Female showed more affinity towards prawns than the male, similarly the larger size group showed higher percentage of prawn compared to smaller size group. The variations in the availability of food organisms in the habits are reflected in the diet of this fish. The study also revealed that *Priacanthus hamrur* is not a bottom feeder because sand grains and other coarse particles were not reported from the gut contents. Premalatha (1997), while working on the food and feeding habits of *Priacanthus hamrur* from south west coast of India, reported that this species had no preferential feeding. Anchovies, small crustaceans and parts of cephalopods were the commonly found food items. Based on the above data it can be inferred that the principal food items of *Priacanthus hamrur* consists of shrimps, crustacean remains and fish juveniles.

Philip (1998) reported that *Priacanthus hamrur* is a carnivorous species feeding mainly on crustaceans (like alima, squilla, crabs, shrimps and euphausids) and teleost fishes. Studies carried out on the food and feeding habits of species like *Priacanthus tayenus* and *P. macracanthus* in the south
east Asian regions like Malaysia (Ambak et al., 1987), Hong Kong (Lester, 1968), Thailand (Chomjurai, 1970; Wetchagarun, 1971) and Panay Islands (Senta, 1978) have also indicated that crustaceans were more preferred food items by priacanthids in those regions.

Seasonal variations in food components of *P. hamrur* can be attributed to the changes in abundance of food organisms due to various environmental factors which affect the availability of food organisms in the habitat. Rao (1984) reported that the principal food items of *Priacanthus macracanthus* were crustaceans and teleosts. *Penaeus* spp., *Metapenaeus* spp. and *Solenocera* spp. were the most important items among crustaceans. Naik (1990) studied the food and feeding habits of Priacanthids (*Priacanthus tyenus, P. hamrur, P. cruentatus, P. blochi*) and also reported that bulls eye are carnivorous species, feeding on fishes, crustaceans and polychaetes. Hobson (1991) reported that *Priacanthus cruenatus* from the Hawaiian reef migrate seaward to feed upon pelagic organisms such as cephalopods and crab megalopa larvae. McFarland (1991) stated that *Priacanthids* are reef dwelling nocturnal planktivorous fishes, which locate their food items through their sense of vision.

Tessy and Inasu (1991, 2003) reported on the food and feeding habits of *Priacanthus hamrur* from Kerala coast. The qualitative and quantitative analysis of gut content showed that the food items comprised of deep sea prawns, prawn tissues, bristles of annelids, invertebrate eggs, animal tissues, fat droplets, pieces and tentacles of coelenterates.

The data on feeding intensity in both the sexes of *Priacanthus hamrur* were found to vary with months considerably during September, 2005-May, 2006. In both the sexes the proportion of fish, which had actively fed, was highest in September, whereas during September, 2006 – May, 2007 also the highest percentage was recorded in the month of September. During September, 2005-May, 2006, the poor feeding was observed in the month of April in both the sexes, whereas during September, 2006-May, 2007 in male poor feeding was seen in February and in female it was May. According to Rao (1984), the low feeding intensity was noticed during November to
December in case of *Priacanthus macracanthus*. The feeding intensity may also be related to spawning activity besides food availability. The feeding intensity was found to be more in smaller size groups compared to larger size groups.

Philip (1998) observed that of young fish food comprised a few smaller crustaceans like *Acetes* spp., megalopa, alima, copepods, amphipods etc. showing a marked preference for crustaceans. Teleost fishes were observed in the stomachs of individuals having a length 100 mm and above. The food items were found to be highly diverse in 141-210 mm size range. The intensity of feeding was high during January to July and low during July to December. He also inferred that no significant relationship existed between the feeding intensity and maturation.

5.2. Length- weight relationship

It is well known that the growth in fishes or in any other animal increases with increase in body length. Thus, it can be said that length and growth of a species are interrelated. Hence, it is possible to construct a mathematical relationship between length and weight, which can be used to compute expected weight from the given length. Huxley (1924), first proposed the allometric growth formula to describe the relationship between length and weight in the form $W = a L^b$. Any deviation of the observed weight from the expected weight should indicate general well being, the fatness or gonadal development of fish (Le Cren, 1951). The length - weight relationship of a fish can be described by a Cube law $W = a L^3$ (where $W =$ weight of fish, $L =$ length of fish and $a =$ constant). The cube law represents a condition in an ideal fish, wherein the fish maintains constant shape (Allen, 1938). Le Cren (1951) preferred to use a non-linear equation $W = a L^n$ (where $W =$ weight of fish; $L =$ length of fish; $a =$ constant equivalent to “C” of cube law and $n =$ constant to be determined empirically). When values of $n = 3$, the above length-weight relationship will assume the form of the cube law. Any departure of value ‘$n$’ from 3 explains the growth patterns of fish. However,
fish normally do not retain shape of the body throughout their life span and the relationship may depart from the so-called Cube law. The reasons for this variations are said to be due to seasonal fluctuations in the environmental parameters, physiological conditions of the fish, sex, gonadal development etc. and these changes will lead to departure from the isometric growth pattern. Therefore, \( W = a L^b \) will be more useful in describing length-weight relationship. The value of exponent ‘n’ in the parabolic equation usually lies between 2.5 and 4.0 (Hile, 1936; Martin, 1949).

The length-weight relationship of *Priacanthus hamrur* in the present study showed that the weight of the fish increased almost as the cube of the length as regression co-efficient was found to be 2.9818 and 2.8360 (during 2005-2006) and 2.9285 and 2.8015 (during 2006-2007) for male and female respectively. From the F-ratio, it is evident that there is significant difference between male and female. From the ‘t’ test, it was confirmed that male followed isometric growth. Whereas female followed allometric growth. It can be inferred that, length-weight relationship of same sized individuals can vary from species to species of the same genus (Gharbi and Ktari, 1981). Besides, the quality and quantity of food consumed may also influence the body weight, along with the other unknown factors. The regression co-efficient of female was found to be lower than male. From this observation, it may be opined that male gained more weight with increase in length compared to female. Even though the ‘b’ values are around ‘3’ it was found that there was significant difference between sexes. Hence, separate equations for both sexes were derived.

During 2005-2006; for male, \( \log W = -1.8666 + 2.9818 \log L \)
\[
\text{Or} \quad W = 0.0136 L^{2.9818}
\]

For female, \( \log W = -1.6816 + 2.8360 \log L \)
\[
\text{Or} \quad W = 0.0208 L^{2.8360}
\]

During 2006-2007; for male, \( \log W = -1.7725 + 2.9285 \log L \)
\[
\text{Or} \quad W = 0.0165 L^{2.9285}
\]
For female, \( \log W = -1.6213 + 2.8015 \log L \)

Or

\( W = 0.0239 L^{2.8015} \)

Philip (1994) stated that the analysis of covariance to test the significance of regression co-efficient in the length-weight relationship of male and female (Priacanthus hamrur), the “b” values differ at 5% level of significance. Also stated that the fish grew stouter with increased length, which was different when compared to the length-weight ratio of Priacanthus hamrur captured from depths beyond 250 m. This may be attributed to the difference in depths at which the fish were caught where there was a distinct pattern in the distribution of the population with respect to age and sex across the depth zone.

Philip and Mathew (1996) studied the length-weight relationship and condition factor of Priacanthus hamrur. They gave the equation for male as \( W = 0.00000638 L^{3.1133} \) and female, \( W = 0.00000811 L^{3.0685} \). The studies on the length-weight relationship of Priacanthus hamrur from north western EEZ of India revealed that there was significant difference between male and female (Varghese, 1988). According to him the values obtained on the length-weight relationship for male was \( W = 0.03766 L^{2.6285} \) and for female \( W = 0.01780 L^{2.8803} \).

Sivakami et al. (2001) reported on the length-weight relationship of Priacanthus hamrur along the Indian coast. According to them, the length-weight relationship of male was \( \log W = - 4.034868 + 2.626081 \log L \) and for female \( \log W = -4.307500 + 2.743857 \log L \). Analysis of co-variance to test the significance of regression coefficient in the length-weight relationship showed that the b values differed at 5% level of significance. Thomas et al. (2003) studied the length-weight relationship of Priacanthus hamrur along the west coast of India. They reported that the length-weight relationship was \( \log W = -1.757 + 2.856 \log L \). Also mentioned that the length-weight relationship depended on the condition of the fish caught during different seasons, the depth of capture, geographical location, sex, length range, sample size etc. Abdurahiman et al. (2004) reported on the length-weight relationship of
*Priacanthus hamrur* in southern coast of Karnataka. According to them, the length-weight relationship of male was \( W = 0.017 L^{2.905} \) and female, \( W = 0.02 L^{2.787} \).

While studying the length-weight relationship of *Priacanthids*, scientists from the adjacent seas of Indian peninsula shared their views. The length-weight relationship of *Priacanthus tayenus* from Gulf of Thailand revealed a value of \( W= 3.16 \times 10^{-6} L^{2.919} \) for male and \( W = 2.60 \times 10^{-6} L^{2.891} \) for female (Chomjurai, 1970). Wetchagarun (1971) noticed little difference in the “b” value of the two sexes of *Priacanthus macracanthus* in the Gulf of Thailand.

Lester and Watson (1985) reported the b value of 2.7 and 2.9 respectively for *Priacanthus tayenus* and *P. macracanthus*, which did not show significant deviation (\( P = 0.05 \)) from isometric. According to Ambak *et al.* (1987) the length-weight relationship for *Priacanthus macracanthus* of Malaysian EEZ was \( W = 0.174 L^{2.349} \). Joung and Chen (1992) noticed little difference in the “b” value of the two sexes of *Priacanthus macracanthus* in Taiwan waters. Liu and Cheng (1999) studied the length-weight relationship of *Priacanthus hamrur* from the waters of northeastern Taiwan. They did not find significant difference in the relationship between length (L) and weight (W) for male and female, hence they gave a combined equation of male and female as \( W = 8 \times 10^{-4} L^{2.23} \).

### 5.3. Relative condition factor

Individual variations from general length-weight relationship have been studied under general name condition (Le Cren, 1951) such changes in “condition” were usually analyzed by means of condition factor or ‘K- factor’ or ‘ponderal index’ given by the formula \( K = 100 \frac{W}{L^3} \) (Hile, 1936; Thomson, 1943) (where \( W = \) weight of fish, \( L = \) length of fish and \( K = \) ponderal index), has often been used to indicate the condition, fatness or general well-being of fish. The value of ‘K’ gets directly affected, if fish does not obey the cube law. Le Cren (1951) suggested that the calculation of relative condition factor (Kn), \( (K_n = \frac{W_o}{W_c}) \) based on the length-weight relationship in order to eliminate the
effects of the length and other factors such as age, sex, maturity, feeding intensity and selection in sampling on condition factor.

Data on seasonal variation in the condition of both male and female during both the years of study showed that the values were more or less similar in both the sexes, thus indicating almost identical metabolic activity in male and female. The high condition exhibited by both the sexes during May ($Kn = 1.1365$ and $1.1254$ for male and $1.1458$ and $1.1377$ for female) may be due to gonadal development and high feeding intensity. Mature gonads appearing conspicuously from March onwards will further support rise in $Kn$ values. Thus, available data suggest that the monthly variation in $Kn$ values may be related to maturity or feeding intensity. It is also possible that some unknown factors may also be playing a role.

The drop in the condition of fish in both the sexes during September, 2005- May, 2006 and during September, 2006- May, 2007, the lowest $Kn$ values were found in October in both the sexes might be due to lowering of gonad weight or occurrence of immature and maturing fish as well as the decreased feeding activity. Among other factors, which influence the coefficient of condition are intensity of feeding, age and sex of the individuals (Everhart et al., 1975), abundance and types of food available and physico-chemical characteristics of the environment. Hart (1946) stated that the $Kn$ values give good idea about broad outline of the seasonal cycle for a species. He observed that apart from seasonal variation, there could be a secondary variation related to the length of fish. However with increase in age there could be a lower level of condition through the seasonal cycle consequent upon the increased metabolic strain or spawning.

The fluctuations in the $Kn$ values with respect to size indicated that the condition of the fish showed more or less an increasing trend with the increase in size of the fish. The highest $Kn$ values observed in male (32-33 cm and 33-34 cm size groups) and female (32-33 cm and 33-34 cm size groups) could be attributed to good feeding. The increase in $Kn$ value from 17-18 cm size group indicated that the fish start maturing around 21-22 cm, whereas sudden
decrease from 24-25 cm and 25-26 cm size groups was probably due to spawning stage. After 26-27 cm size, the increase in Kn was more rapid indicating possible recovery after spawning which had a more marked effect on the Kn value of the female fish than that of male.

From the present observation, it can be inferred that the variation in the condition of *P. hamrur* is due to feeding activity and probably other unknown factors. James (1967) opined that the changes in the condition of *Eupleurogrammus intermedius* were probably related to factors other than reproductive cycle and feeding habits. Philip and Mathew (1996) studied the length-weight relationship and condition factor of *Priacanthus hamrur*. An inflection in the Kn value prior to the onset of maturity indicating the physiological changes that the fish undergoes was observed in some species of the north east coast (Reuben *et al.*, 1994). However, in *P. hamrur* no such inflection was observed prior to or during the size at first maturity, indicating that the sexual cycle of this fish doesn’t have any profound influence on the condition of the fish. The gastro-somatic index of *P. hamrur* was reported by Philip (1994) and comparison of monthly values of relative condition factor and gastro-somatic values showed a very strong correlation. It may therefore, be inferred that the condition of *P. hamrur* is greatly influenced by feeding intensity rather than the cyclic changes taking place in the gonads.

**5.4. Reproduction**

Fishes exhibit periodic or cyclic reproductive behavior. A thorough knowledge of maturation cycle will help to understand and predict the annual changes that a population undergoes. This involves morphological and histological observations like changing pattern of the structure and condition of the gonads are used to ascertain the maturity stages. The term maturity stage means the degree of ripeness of the gonad. Periodical microscopic and histological examination of testes and ovaries for at least one year helps in understanding the progression and depletion of gonads throughout the maturation cycle. Fish biologists have devised schemes to identify maturity in
different stages, usually 4 to 5 or even up to 7 to 8 stage (Clark, 1934; Hickling and Rutenberg, 1936; Prabhu, 1956; Qasim, 1973; Crossland, 1976).

It is well known that in most fishes there is a marked seasonal periodicity in egg production. Based on ova diameter studies of ovaries well advanced towards spawning, teleostean fishes have been found to exhibit different types of spawning habits (Hickling and Rutenberg, 1936; Dejong, 1940; Prabhu, 1956; Qasim and Qayyum, 1961; Annigeri, 1967). These observations indicated four major groups of fishes depending on their spawning habits as given below.

**Group I:** Fishes in this group have short spawning, once a season. The ova diameter frequency polygon of the mature ovaries of such fishes show only two distinct groups of ova, the immature and the mature, well separated from each other.

**Group II:** Fishes in this group spawn only once, but over a long period of time, wherein, the range in size of the mature ova will be approximately half of the total range of all ova.

**Group III:** This group is constituted by fishes which spawn twice in a season, wherein apart from the mature and immature group of ova, one more group of ova following the mature group is seen, which has undergone about half maturation process. This represents the maturing group of ova.

**Group IV:** Fishes of this group spawn intermittently over a long period. In the ovaries of successive batches of ova are not clearly differentiated indicating that the maturation process is a continuous one.
A perusal of data on the temporal distribution of maturity stages of *Priacanthus hamrur* shows that ovaries in stages I, II, and III were represented more during September, December, while those in stage IV and V were less frequently encountered with their peak during November and from February to May. Ripe ovaries in IV, V and VI stages were represented mainly during March – May with less frequently during October and November. Ovaries in spent condition were encountered more from May to September. Since the occurrence of ripe gonads were more during March to May with higher incidence of the spent ones from May to September, it may be concluded that *P. hamrur* from Mangalore waters have an extended spawning season and also may be coinciding with southwest monsoon. However, since ripe gonads were noticed during October and November also, it is possible that the species breed during this period also. Vijaya Kumaran and Naik (1989) inferred a southward shallow water migration of *Priacanthus* spp. during the pre-monsoon months for breeding purpose. It is apparent that *Priacanthids* along the Karnataka coast undertakes an onshore migration from deep water (200-500 m) in the monsoon period to shallow waters (20-60 m) in the pre-monsoon months.

Tapia *et al.* (1995) studied the reproduction of *Priacanthus arenatus* in the continental shelf of Gulf of Mexico. They reported that this species spawns in March (dry season) near Puerto real inlet, around the 11m isobath. Recruitment occurs in the area of reproduction from March to June. Studies on the reproductive biology of big eye *Priacanthus macracanthus* from East China Sea (Oki *et al.*, 1999) revealed that the spawning peak was found to be in May and June. Liu *et al.* (2001) studied the reproductive biology of the big eye *Priacanthus macracanthus* in north-eastern Taiwan waters.. They employed four methods, viz. macroscopic appearance of ovary, gonado somatic index, oocyte diameter frequency distribution and histological examination of gonad and suggested that the spawning season of the big eye in the north-eastern Taiwan waters lasts from April to July and peaks in May and June. Premalatha (1997) studied the reproductive biology of *Priacanthus hamrur*. Adult fishes in ripe and running stages were obtained in March- April period when 80% of the
samples collected were fully matured. In the year 1995 most of the ripe specimen were obtained in March while, in 1996 they were found in April. Sivakami et al. (2001) studied the reproductive biology of *Priacanthus hamrur* along Indian coast. Based on occurrence of ripe gonads during April to July with higher incidence of the spent ones, the authors concluded that *P. hamrur* off Cochin had an extended spawning season during April to July shedding two batches of ova. However, since ripe gonads and spent gonads were noticed during November – December also, it is also possible that the species breed during this period also. One batch of well-differentiated ova followed by a secondary batch of developing ova was discernible in the ripe ovary. Since the secondary batch contains rather large yolkeed ova reaching more than half of the diameter of the first batch of ripe ova and since they form about 29% of the total ova size frequency, it is possible that this secondary batch also will be shed during the extended spawning season during April-July period. Further off Mumbai the authors observed that *Priacanthus hamrur* were mainly in immature and maturing stages with lesser frequency of the matured gonads and with no ripe or spent ovaries recorded even in larger specimen. The immature and maturing ovaries formed 72.73% during May and 100% during February, April, July, September and November while, mature ovaries formed 9.09% during January and 100% during June.

Robertson (1991) stated that the regional variations in spawning frequencies in reef fishes like *Priacanthids* may be correlated with gross seasonality of the environmental variables such as water current, wind pattern, seasonal cycles of the primary productivity, temperature and day length which may affect the food supply, growth and dispersal of the larvae.

The gonado-somatic indices of *P. hamrur* were recorded in different months to confirm the spawning period. It was found that the lowest GSI values were recorded in January while highest in May. The GSI values gradually increased from February to May and declined in the month of September, thereafter the GSI values increased in the month of October and November. In the present study, it can be said that the spawning season of the
*P. hamrur* extends from March to May and October and November along the Mangalore coast.

Based on percentage occurrence of mature fishes in various size groups it was found that male attained maturity at smaller size than female. The size at first maturity of male was at 21.10 cm and female at 22.20 cm during September, 2005- May, 2006 whereas, during September, 2006 – May, 2007 the size at first maturity of male was at 21.20 cm and female at 22.10 cm. The size at first maturity was calculated from the relative condition factor. The peak point on a curve showing the dominance of relative condition with increasing length is a good indication of length at which seasonal maturity is attained (Hart, 1946). It was found that male and female attained sexual maturity at 21 – 22 cm and 22 – 23 cm respectively.

On the other hand, the mean size at first maturity, calculated by the method of Udupa (1986), was found to be 21.21 cm for male (95% confidence limits ranging between 22.52 and 22.54 cm) and 22.31 cm for female (95% confidence limits ranging 23.62 and 23.65 cm) during September, 2005 – May, 2006. During September, 2006- May, 2007, it was found to be 21.29 cm for male (95% confidence limits ranging between 22.60 and 22.63) and 22.61 cm for female (95 % confidence limits ranging 23.95 and 23.98 cm). The differences in the values of size at first maturity are related to the difference in the methods followed. Other workers who have worked on reproduction of *Priacanthus hamrur* have indicated more or less similar values. Premalatha (1997) studied the reproductive biology of *Priacanthus hamrur* along south west coast of India. The author reported that the size at first maturity was 175 mm for male and 190 mm for female. Oki *et al.* (1999) while working out the relationship between fork length and frequency of matured specimen reported that the size at first maturity was 190 mm. Liu *et al.* (2001) recorded the size at first maturity as 18.9 cm FL estimated from the logistic model. Sivakami *et al.* (2001) reported that the size at first maturity of male and female as 181-190 mm and 191-200 mm respectively.
Knowledge of total number of eggs produced by a fish in a year is important for determining the spawning potential of a fish. Fecundity is usually determined from the number of ova of the mature group in the ovary. In the present study, fecundity of *Priacanthus hamrur* was found to vary from 1,57,268 to 4,13,648 eggs with an average 2,53,917 eggs depending upon the size of the fish (19.8cm to 32.50cm TL).

Along the Indian coast, Sivakami et al. (2001) reported that the fecundity for *Priacanthus hamrur* ranged between 1,55,800 to 7,22,313 eggs with an average of 3,80,072, whereas Rao (1984) reported fecundity of 1,09,411 eggs for *P. macracanthus* from Waltair coast. In case of *P. macracanthus* from the East China Sea, the fecundity was found to vary from 70,000 at 190 mm fork length to 2, 30, 000 at 250 mm fork length (Oki et al., 1999). Liu et al. (2001) reported that the mean fecundity value for *P. macracanthus* was found to be 1,31,112, ± 33379 from Taiwan waters.

In the present study the logarithmic relationship of fecundity on length, weight and ovary weight was found to be linear indicating that the number of ova increased generally with increase in length and weight of fish.

The variation in the sex-ratio invariably indicates differential fishing (Kesteven, 1945). It may indicate the difference in the growth rate of two sexes (Qasim, 1966). In the present study the sex-ratio studies indicated the dominance of female in most of the months of sampling. The sex ratio of male to female was found to be 1.00: 1.46 and 1.00:1.20 during the period September, 2005 – May, 2006 and September, 2006 – May, 2007 respectively. Chi-square test showed significant deviation from the theoretical ratio of 1:1. Variation in sex-ratio values may be attributed to the following reasons: 1) segregation of sexes through various periods of the year including segregation resulting from sex differences in age and size at first maturity. 2) Gear selectivity in relation to sex differences in morphology and physiological activity and 3) Differences in natural and fishing mortality between sexes. Zacharia et al. (1991) reported that females of *P. hamrur* were found to be dominant in commercial catches from Mangalore waters. The sex-ratio was F:
M = 1.6:1.00. The observation of Sivakami et al. (2001) on the sex-ratio of *P. hamrur* along Indian coast indicated that females were dominant in the population except during April, July and December.

### 5.5. Age and growth

A sound knowledge of the age and growth of fish species contributing to the fishery is essential in understanding, among others, the longevity of exploited stocks, the age composition of the catch, the age at sexual maturity, the suitability of different environments for growth, other population dynamics and the possible identification of stocks on the basis of differences in growth rates.

The present study revealed the following Von-Bertalanffy growth equation $L_t = 34.10 \left[ 1 - e^{-0.37 (t+0.1743)} \right]$ for male and $L_t = 34.00 \left[ 1 - e^{-0.45 (t+0.1606)} \right]$ for female. The growth increment obtained were 6.83 cm, 4.71 cm, 3.26 cm, 2.25 cm, 1.56 cm, 1.07 cm and 0.74 cm for male and for female 7.31 cm, 4.66 cm, 2.97 cm, 1.90 cm, 1.20 cm, 0.72 cm and 0.50 cm during the I to end of VII year of its lifespan.

Chakraborthy (1994) studied the age and growth of *Priacanthus hamrur* and the author reported that this species grows to 193, 283 and 323 mm at the end of 1, 2 and 3 years respectively from Bombay waters. The Von Bertalanffy’s growth parameter in length were estimated as follows $L_\infty = 360$ mm, $K = 0.736$ (annual) and $t_o = 0.009116$ years while, Chakraborthy et al. (1994) recorded $L_\infty = 345.5$ mm and $K = 0.66$/year for the same species. Chakraborthy and Vidysagar (1996) obtained a growth increment of 171 mm, 89 mm, 48 mm and 26 mm during I to IV years. Von Bertalanffy’s growth parameters $L_\infty = 360$ mm, $K = 0.64$/year for *Priacanthus hamrur* from northwest coast of India.

Philip and Mathew (1996) studied the age and growth of *Priacanthus hamrur* from the northeast coast of India. They estimated the values of $L_\infty$, $K$, $t_o$. Thus VBGF for male, $L_t = 297.0971 \left( 1 - e^{-0.3585 (t + 0.0206)} \right)$ for female, $L_t = 300.4580 \left( 1 - e^{-0.3826 (t + 0.0244)} \right)$ and for combined sexes, $L_t = 283.9278 \left( 1 - e^{-0.3722 \times (t + 0.0206)} \right)$.
are provided by them. They also recorded the VBGF corresponding to the weight for the above sets of data derived using the length-weight relationship, for male \( W_t = 318.8553 \left(1-e^{-0.3585 (t + 0.0206)}\right)^3 \), for female \( W_t = 323.2419 \left(1-e^{-0.3826 (t + 0.0244)}\right)^3 \) and for both the sexes \( W_t = 274.2867 \left(1-e^{-0.3722 (t + 0.1122)}\right)^3 \). The growth parameters of male and female of \( P. hamrur \) showed that male exhibited a slower growth rate when compared to female, a corresponding difference in the asymptotic length could also be seen. The value of \( K \) obtained was almost nearer to the average of the same estimated for the male and female for exploratory data.

However, they also stated that along the east coast, the growth increment obtained were 96mm, 59 mm, 40 mm, 27 mm, 20 mm, 13 mm, 9 mm, 6 mm during the I-VIII year of its lifespan. It is therefore evident that growth rate of \( P. hamrur \) off upper east coast is slower than their counterpart in the west coast which is further substantiated by the lower \( L_{max} \) (262 mm) obtained along the east coast. The reason for this may be attributed to the narrow continental shelf along the east coast with deeper waters inhabitation of \( P. hamrur \), which tends the species to share some characters of temperate species such as slow growth rate and extend lifespan. Bhargava et al. (2004) studied the age and growth of \( Priacanthus hamrur \) along North – West coast of India. They reported \( L_{\infty} = 37.40 \text{cm}, K=0.64 \) and lifespan of about 7-8 years.

Sivakami et al. (2005) studied the age and growth pattern of \( P. hamrur \) along the west coast of India. They gave the growth equation as \( L_t = 410 \left(1-e^{-0.59 (t - 10)}\right) \). The fish was found to attain a length of 182.7 mm, 284 mm, 340.2 mm, and 371.3 mm during I, II, III and IV years respectively. The maximum size of the species in the fishery off west coast was 368 mm TL, the age of which is estimated as 3.86 years.

In the light of the available information, the growth parameters \( L_{\infty}, K \) and \( t_o \) obtained in the present study, are in close agreement with the earlier workers (Chakraborthy, 1994; Philip and Mathew, 1996; Bhargava et al., 2004), however Sivakami et al. (2005) reported a slightly higher values of \( L_{\infty} \) and \( K \).
5.6. Population dynamics

The present study inferred that the total, natural and fishing mortality rates of *Priacanthus hamrur* were 1.44, 0.91 and 0.53 respectively.

The estimated exploitation ratio (E) and exploitation rate (U) for *Priacanthus hamrur* were 0.37 and 0.28 respectively.

The estimated probability of capture (Lc) length at which 25 percent of fish (L_{25}) will be vulnerable to the gear was 19.38 cm, length at which 50 percent of fish (L_{50}) will be vulnerable to the gear was 23.29 cm and L_{75} was at 28.10 cm.

From the relative yield per recruit diagram, it is seen that the maximum could be obtained when the exploitation ratio is 0.37, the relative biomass will be reduced to 52% of the exploited phase.

From the relation between biomass, yield and effort multiplier, the present level of biomass and yield were assessed at 43,890 t and 1,055 t respectively.

Based on the present condition of exploitation of the stock of *Priacanthus hamrur* off Mangalore coast, the exploitation ratio (E) was 0.37 (less than 0.5) indicating that the stocks are not being exploited at optimum level in recent years.

Chakraborthy (1994) observed that the total mortality, natural mortality and fishing mortality coefficients of *Priacanthus hamrur* from Bombay waters were Z=3.08, M= 1.56. The exploitation ratio (E), exploitation rate (U) were calculated as 0.506 and 0.482 respectively. The standing stock (Y/F) and total stock (Y/U) were estimated at 332 t and 1,074 t respectively.

Philip and Mathew (1996) studied the Mortality and Exploitation of *Priacanthus hamrur* from the north east coast of India. The natural mortality M, the total mortality Z and fishing mortality F reported by them were

For male M = 0.9000, Z = 2.4514 and F = 1.5514

For female M = 0.9363, Z = 1.7686 and F = 0.8323

For both sexes M = 0.9341, Z = 2.5047 and F = 1.5706
The Exploitation ratio \( E \) and Exploitation rate \( U \) were

For male \( E = 0.6329 \) and \( U = 0.5783 \), for female \( E = 0.4706 \) and \( U = 0.3903 \), for both the sexes \( E = 0.6271 \) and \( U = 0.5758 \).

Sivakami et al. (2005) studied the fishery potential of bulls eye along the west coast of India. They reported the annual mortality rates of *Priacanthus hamrur* for the period 2000-2004 for North West and south west coast. Along northwest coast the parameters during the year 2000 were \( Z = 5.15 \), \( M = 1.14 \) and \( F = 4.01 \), in the year 2001 were \( Z = 6.14 \), \( M = 1.14 \) and \( F = 5.00 \), in the year 2002 were \( Z = 5.08 \), \( M = 1.14 \) and \( F = 3.94 \); in the year 2003 were \( Z = 4.60 \), \( M = 1.14 \), and \( F = 3.46 \), and in the year 2004 were \( Z = 4.46 \), \( M = 1.14 \) and \( F = 3.32 \). The average values were \( Z = 5.09 \), \( M = 1.14 \) and \( F = 3.95 \). In the case of southwest coast the values for the year 2000 were \( Z = 5.45 \), \( M = 1.14 \) and \( F = 4.31 \), for the year 2001 were \( Z = 3.99 \), \( M = 1.14 \) and \( F = 2.85 \), for the year 2002 were \( Z = 4.47 \), \( M = 1.14 \) and \( F = 3.63 \), for the year 2003 and 2004 were \( Z = 2.27, 4.79 \), \( M = 1.14, 1.14 \) and \( F = 1.13, 3.65 \) respectively. The average values were \( Z = 4.25 \), \( M = 1.14 \) and \( F = 3.11 \).

The total mortality coefficient \( Z \) along the northwest coast ranged between 4.46 to 6.14 during the period 2001 to 2004 with an average of 5.08. The annual mortality \( M \) was 1.14 and the fishing mortality \( (F) \) ranged between 5 and 3.32, the average being 3.95.

Along the south west coast, total mortality \( Z \) obtained was high (5.45) during 2000, which however indicated a fluctuating pattern with lesser values realizing during 2001 (3.99) and during 2003 (2.27), the average being 4.25. Taking the natural mortality \( M \) as 1.14 (common for west coast), the fishing mortality ranged between 4.31 during 2000 to 1.13 during 2003. The average \( F \) was 3.11. The relative yield / recruit the smallest of *P. hamrur* caught off northwest coast and south west coast belong to the size group of 110-119 mm and the corresponding \( (t) \) was 0.53 years or 6.4 months. However, the length at the capture of this species off north west coast belong to the size group of 230-239 mm, the corresponding \( t \) being 1.4 years. Along the south west coast, the length at first capture was within the size group 210-219 mm. The Exploitation
ratio (E) off northwest coast was 0.78. The optimum yield/recruit and the optimum biomass/recruit were 3.6 g and 0.5 g respectively. Off south west coast, the exploitation rate (U) was 0.77 the exploitation ratio E was 0.73 and the $E_{\text{max}}$ 0.802. The optimum yield/recruit and the optimum biomass/recruit were 3.54 g and 0.104 g respectively. The exploitation rate (U) was 0.719. The annual yield of *P. hamrur* off north west coast during 2000-2004 was 6,293 t. The estimated annual stock was 8,173 t and the average standing density 2,069 t.

Lester and Watson (1985) studied the population parameters of *Priacanthus tayenus* and *Priacanthus macracanthus* in the South China Sea. They reported a total annual instantaneous mortality of $Z = 2.00$, for *Priacanthus tayenus* calculated based on adjacent catch curves and a mean length equation. The natural mortality rate $M = 1.4$, fishing mortality rate $F = 0.6$ and the exploitation rate (E) was 0.27. Whereas for *Priacanthus macracanthus* the population parameters were $Z = 2.00$, $F = 0.7$ and $E = 0.34$. Joung and Chen (1992) analysed population parameters of the big eye *Priacanthus macracanthus* in the waters off northeastern Taiwan. Total mortality estimated ranged from 0.88 to 1.97/ year. In the year 1984 values were $Z = 0.88$, $M = 0.37$ and $F = 0.51$; in 1995 were $Z = 1.36$, $M = 0.33$ and $F = 1.03$; in 1996 were $Z = 1.97$, $M = 0.33$ and $F = 1.64$; in the year 1997 were $Z = 1.56$, $M = 0.33$ and $F = 1.24$. The mean values of $Z = 1.44$, $M = 0.34$ and $F = 1.11$. Natural mortality estimated from the equation of Pauly (1980) equation was stable $0.33 - 0.37$/ yr.

From the foregoing account, it is clearly evident that the values of population characteristics of *P. hamrur* varied considerably from region to region and from place to place. Further, it may be inferred that the values do show minor variations possibly owing to regional variations in fishing status, biological characteristics and environmental parameters (water temperature, shift of currents and changes of sea level and wind stress etc).

**VI. SUMMARY**
The Bulls eye, *Priacanthus hamrur* is an important deep-water inhabitant of great commercial value. It finds a place in the market in diversified forms. Presently it has great demand in Singapore, Thailand, Taiwan, Hong Kong and other countries. Exploratory survey conducted by Fishery Survey of India has indicated that there is vast scope for exploitation from this resource. Nearly 40,000 tonnes of Priacanthids are available for exploitation in Indian EEZ and as such these priacanthids can immediately replace the already overexploited coastal verities (Sudarsan *et al.*, 1988). Thus, in the light of its importance, the present study was aimed at investigating into the fishery, biology and population characteristics of *Priacanthus hamrur* from Mangalore waters. The study was carried out during September, 2005 to May, 2007. The important findings of the investigation are as follows.

1. Priacanthids are generally caught by trawl nets and they formed 1.2 % and 1.4 % of the total catch during the period September, 2005 to May, 2006 and September, 2006 to May, 2007 respectively.

2. The qualitative and quantitative analyses of gut contents of *Priacanthus hamrur* revealed that this species fed mainly on shrimps, crustacean remains and fish juveniles. Teleosts, juveniles of squids, crab, cuttlefish and octopus were next in abundance in the gut contents. These findings show that *Priacanthus hamrur* is a carnivorous species feeding on free swimming organisms near to the bottom. The absence of sand grains, detritus, benthic organisms in the stomach of *Priacanthus hamrur* indicate that they do not browse at sea bottom for food.

3. The percentage occurrence of shrimps in the stomach contents in both the sexes of *P. hamrur* were found to vary with months considerably. During September, 2005-May, 2006, the highest percentage of shrimps was found in September in both the sexes, whereas during September, 2006-May,
2007, the highest percentage in male, was seen in October and in female during the month of September. The lowest quantity of shrimps was noticed in the month of May in both the sexes during September, 2005-May, 2006. During September, 2006 to May, 2007, the lowest in male was in May, while in female, it was in March and May. These monthly variations may be due to the factors such as relative abundance of shrimps, its consumption rate and age of fish. The high percentage of shrimps in the months of September and October may be due to the abundance of this item in the environment after south west monsoon.

4. The analyses of food revealed that, in all the size groups starting from 14-15 cm to 33-34 cm, food items such as shrimps, semi-digested matter, crustaceans remains and fish juveniles, teleosts, juveniles of squids, octopus juveniles, crab juveniles, cuttlefish juveniles were found in different proportions. During September, 2005- May, 2006, shrimps were the most dominant item in all the size groups, although they occurred in different proportions. In both the sexes the highest percentage was recorded in the size group 30-31 cm and the lowest in the size group 15-16 cm. During September, 2006- May, 2007, highest percentage was recorded in male in the size group 31-32 cm and lowest in the size group 14-15 cm. In case of female, highest percentage was in the size group 30-31 cm and lowest in the size group 14-15 cm. Female showed more affinity towards shrimps than male. Larger size group (20-33 cm) showed higher percentage of shrimps compared to smaller size groups (15-21 cm).

5. The regression co-efficient of female was found to be lower than male. From this observation it may be opined that male gained more weight with increase in length compared to female. Even though ‘b’ values were around ‘3’, it was found that there was significant difference between sexes. Hence, separate equations for sexes were derived.

During 2005-2006; for male, \( \log W = -1.8666 + 2.9818 \log L \)
for female, \( \log W = -1.6816 + 2.8360 \log L \)
During 2006-2007; for male, \( \log W = -1.7725 + 2.9285 \log L \)
for female, \( \log W = -1.6213 + 2.8015 \log L \)

6. Data on seasonal variation in condition (Kn) of both male and female during both the years of study showed that the values were more or less similar in both the sexes, indicating almost identical metabolic activity in male and female. The high condition (Kn) was observed during May, 2006 (1.1365 for male; 1.1458 for female) and May, 2007 (1.1254 for male; 1.1377 for female), which may be attributed to gonadal development and high feeding intensity. Mature gonads appearing conspicuously from March onwards will further support rise in Kn values. Thus, available data suggest that the monthly variation in Kn values may be related to maturity or feeding intensity, but also could be due to unknown factors.

7. The fluctuations in the Kn values with respect to size indicated that the condition of the fish more or less showed an increasing trend with the increase in size of fish. The highest Kn values observed in male (32-33 cm and 33-34 cm size groups) and female (32-33 cm and 33-34 cm size groups) can be attributed to intensive feeding. The increase in Kn value from 17-18 cm size group onwards indicated that fish start maturing around 21-22 cm, whereas sudden decrease in 24-25 cm and 25-26 cm size groups were probably in the spawning stage. After the size group 26-27 cm, the increase in Kn was more rapid indicating possibly the recovery of fish condition after spawning had marked effect on the Kn value of female than that of male. From the present observation, it can be said that the variation in the condition of \( P. \) hamrur was due to feeding activity.

8. Studies on reproductive biology showed that \( P. \) hamrur spawns twice in a year, the spawning season extending from March to May and October to November along the Mangalore coast.
9. Based on the percentage occurrence of mature fishes in various size groups it was inferred that male attained maturity at smaller size than female. The size at first maturity of male was at 21.10 cm and female at 22.20 cm.

10. Fecundity of *Priacanthus hamrur* was found to vary from 1,57,268 to 4,13,648 eggs with an average of 2,53,917 eggs depending upon the size of fish.

11. The sex-ratio indicated the dominance of females over males and ratio was found to be 1.6:1.00. However, the females were dominant in the population in all the months except during April, July and December.

12. Von-Bertalanffy growth equation estimated for this fish as follows:

\[ L_t = 34.10 \left[ 1 - e^{-0.37(t+0.1743)} \right] \text{ for male and } L_t = 34.00 \left[ 1 - e^{-0.45(t+0.1606)} \right] \text{ for female.} \]

13. The total, natural and fishing mortality rates of *Priacanthus hamrur* were 1.44, 0.91 and 0.53 respectively. While the exploitation ratio (E) and exploitation rate (U) estimated were 0.37 and 0.28 respectively.

14. The estimated probability of capture (Lc) of fish, the length at which the 25 percent of fish (L_{25}) vulnerable for capture by the gear was 19.38cm, length at which 50 percent of fish (L_{50}) vulnerable for capture by the gear was 23.29cm. Similarly for L_{75} the value was at 28.10 cmTL.

VI. REFERENCES