DISCUSSION
5. DISCUSSION

The potential benefits of hybridisation include i) hybrid vigour in F hybrids, ii) introgression of genes i.e., transfer of small number of genes from one genetic group to another to correct specific faults, ii) creation of gene pool, iv) combination of specific qualities of different species in single fish and v) production of sterile and monosex hybrids (Moav, 1976; Tripathi, 1990). Extrapolating from the evidence found in carp, it may be inferred that the single step mating of unrelated individuals for the production of hybrid should improve growth rate, and viability. Such an approach has resulted in the large scale production of F individuals (Moav, 1976; Moav et al., 1976; Eknath et al., 1991b).

In the present study the hybrids were produced between Catla catla and Labeo fimbriatus. Both the species
belong to the family cyprinidae. As is well known catla is the fastest growing Indian major carp. But the disadvantage with this species is that it has a big head which reduces the meat yield. Fimbriatus is an indigenous medium carp, esteemed for its flavour and quality flesh and ready response to induced breeding (Devaraj et al., 1986). Because of its slow growing nature (Manissey et al., 1986) it is not commonly included in aquaculture practice. Thus the hybrid produced between these two species would be of considerable interest, if it could combine the fast growing habit of catla and easier breeding in captivity and flesh quality of fimbriatus.

A proper evaluation of the potential of hybrids for aquafarming requires a good knowledge of their characteristics. Their value may in fact result from one or a combination of several of these features (Chevassus 1983). The important parameters that have to be examined are physiological characters (most frequently, length of embryonic period), morphometric or numerical characters, biochemical characters (especially electrophoretic patterns), growth potential and other farming attributes. In the present study, the hybrids were evaluated on these lines to find out their equacultural potential.
The findings of the present study are discussed in the above context and in the light of the earlier published work with special reference to carp hybrids. Except for the present study, no detailed information is available on the intrinsic qualities of these hybrids, although one of them (Catla-fibriatus) was produced way back in 1963 (Anon., 1963).

5.1 Fertilisation of eggs, incubation period and larval rearing.

The rate of fertilization of eggs in hybrids is dependent on the ambient water temperature and the parents involved in hybridisation. The percentage of fertilization showed a wide variation among different carp hybrids and is reported to be generally high (Konda Reddy, 1977; Basavaraju and Vargheese, 1981, 1983; Ibrahim et al. 1980; Ibrahim et al., 1986; Basavaraju et al. 1989; Gupta et al., 1989). Ibrahim et al. (1980) reported 82 to 100 per cent fertilization at a water temperature of 28 to 31°C in silver carp-catla hybrid. Basavaraju et al. (1989) observed that percentage of fertilization in rohu-fibriatus hybrid was 88.55 per cent (water temperature 27.5°C). In hybridisation involving common carp as a female parent the fertilization rate is low and this has been attributed to adhesive nature of eggs and improper and incomplete degumming of eggs (Ibrahim et al., 1986; Gupta et al., 1989; Khan et al., 1989). In
the present study, as reported earlier in Indian carp hybrids, the rate of fertilisation was high in both the hybrids.

The variation observed in size of fully swollen eggs is obviously due to variation in the rate of water absorption and ambient water temperature (Chakrabarty and Murty, 1972; Konda Reddy, 1977). In the present study, the size of fully swollen eggs of hybrids were intermediate between parent species with a mean diameter of 4.75 mm in catla, 3.95 mm in fibriatus, 4.11 mm in catla-fimbriatus and 4.06 mm in fibriatus-catla, as observed by Basavaraju (1978) in case of rohu-mrigal and mrigal-rohu hybrids. However, in case of catla-rohu hybrids the fully swollen eggs were bigger than those of catla and rohu, while in the reciprocal hybrid they were smaller than both the parents (Konda Reddy, 1977). In hybridisation involving common carp, the size of eggs appear to lean more towards common carp (Gupta et al., 1989; Ibrahim et al., 1986; Khan et al., 1989). Thus the egg size in hybrids appear to be dependent of species involved in hybridisation, water temperature and rate of water absorption and is not of much significance in distinguishing hybrids from parent species.

5.1.1 Incubation period and hatching rate

Varying incubation periods have been reported for different carps and their hybrids ranging from 14 to 18 hours.
of catla, fimbriatus, catla-fimbriatus and fimbriatus-catla respectively).

The foregoing account indicates that the incubation period varies widely among carp hybrids depending on the parents involved and the ambient water temperature. is not indicative of any particular feature that demarcates hybrids from parent species though, Makeyeva (1975) and Chevassus (1983) stated that the length of embryonic period could be used as one of the parameters for identification of hybrids in cyprinides. Blanc and Chevassus (1979) indicated that the ploidy of the hybrid and also the genetic distance of the parents may modulate this parameter.

The hatching rate of hybrids and parent species in the present study was quite high. The hatching rate in catla fimbriatus was intermediate (73.25%) between parents in catla (70.37%) and fimbriatus (85.63%), while in case of fimbriatus-catla it was less than both the parents (69.33%). Not much information is available on the hatching rate of carp hybrids. The hybrids involving common carp showed less low hatching rate as seen in case of mirgal-common carp where it was 40 to 50 per cent (Gupta et al., 1989) and in rohu-common carp (Khan et al., 1989) it was 35 to 40 per cent.
The larvae were maintained in hapas fixed in the margins of reservoir till the absorption of yolk-sac and later transferred to well prepared nurseries. The water quality parameters were analysed frequent intervals and found be within the optimal range as suggested by (Stikney, 1979; Jhingran and Pullin, 1988; Jhingran, 1991).

5.1.2 Pro-larval development

The newly hatched larvae of both the hybrids and parent species are transparant, devoid of mouth pigments and gills, as observed by Khan (1943) and Chakrabarty and Murty (1972) in respect of major carps; Konda Reddy (1977), Basavaraju and Varghese (1981, 1983); Gopal (1988) in case of major carp hybrids and Ibrahim et al. (1980), Kowtal and Gupta (1984), Ibrahim et al. (1986); Gupta et al. (1989) and Khan et al. (1989) in case of Indian and exotic carp hybrids. The yolk-sac has two portions, an anterior bulbous portion and elongated posterior portion in all the four breeds. The posterior portion of the yolk-sac was tapers to a pointed end in both the hybrids, while it was blunt in case of parents. This character does not appear to be of much significance as it varies from fish to fish. Konda Reddy (1977) reported that in the hybrid, catla-rohu, the posterior portion of yolk was tapering to a sharper and than the rohu-catla where it was blunt. According to Basavaraju
and Varghese (1981, 1983), the posterior portion of the yolk-sac was blunt in case of rohu-mrigal hybrid, while it was tapering to a sharp end in the reciprocal hybrid, mrigal-rohu.

The zero hour old hatchling of catla has 26 pre-anal and 12 post-anal myotomes. The post-anal myotomes increased to 15 in 12 hour old larvae, while the number of pre-anal myotomes remained unchanged. In case of fimbriatus, number of myotomes in zero hour old hatchling was same that of catla (26 +12). The number of pre-anal and post-anal myotomes increased to 27 and 13 respectively in 12 old hatchling. In case of hybrids, the number of myotomes in zero hour old hatchlings were less [24 +12 in catla-fimbriatus and 18 +10 in case of fimbriatus-catla] than both the parents. The number of myotomes increased to 38 (26 +12) in 12 hour old hatchings and to 42 (28 +14) in 24 hour old hatchlings of catla-fimbriatu, while the number increased to 38 (22 +16) and 40 (26 +14) during the same age in fimbriatus-catla hybrid. Konda Reddy (1977) reported that the number of myotomes in catla-rohu hybrid was found similar to that of catla while that of rohu-catla was equal to the number found in rohu. The number of myotomes in rohu-mrigal was intermediate to that of the parents (Basavaraju and Verghese, 1981) whereas in the reciprocal cross, mrigal rohu it was
equal to that of mrigal (Basavaraju and Varghese, 1983). Gopal (1980) also opined that there is not much variation in number of myotomes in pro-larval stage of catla-mrigal and mrigal-catla hybrids and their parent species. It is therefore, the number of myotomes are not of much help in distinguishing hybrids from the parents as the number varies from fish to fish.

As reported by earlier workers (Chakrabarty and Murty, 1977; Konda Reddy, 1977; Basavaraju and Varghese, 1981, 1983; Gupta et al., 1989; Khan et al., 1989), in the present study also the eyes are fully pigmented in 12 hour old hatchlings in all the four breeds though the eyes were slightly pigmented in six hour old hatchling of fibriatus-catla hybrid. The pectoral fin bud appeared in 12 hours old hatchlings of all the four breeds. Similar observations were also made by Konda Reddy (1977); Basavaraju and Varghese (1981, 1983) and Gopal (1980) in case of major carp hybrids. The mouth was formed in one day old larvae in both hybrids and parents. The intestine appeared for the first time in 48 hour old hatchlings of all the four breeds which is in agreement with the observations of Kamal (1967); Chakrabarty and Murty (1972); Basavaraju (1978) and Gopal (1980). Konda Reddy (1977) found the intestine of two days old larvae of catla-rohu and rohu-catla was filled with
the algal matter and some cladocerans indicating that they commence feeding on the second day itself. However, in the present study, food items were seen only in three days old larvae.

In all the four breeds, the yolk-sac was almost completely absorbed in three days old larvae and seen only as a thin tube. Mouth was well developed and slightly inferior in both the hybrids, while it was upturned in catla and inferior in fimbriatus exhibiting an intermediate feature between parent species.

5.1.3 Body measurements

The two way analyses of variance test indicated that the pre-dorsal length, length of yolk sac and weight of body did not significantly differ between the hybrids and parents, while other body measurements were highly significant at one per cent level. The height of yolk-sac gets gradually reduced with the advancement of age. Length of yolk-sac increased up to 24 hour after hatching and later showed a decreasing trend. All other body measurements showed a gradual increase with the advancement of age.

At the end of pro-larval stage, the size attained by catla-fibriatus hybrid was more than both the parents while, it was intermediate to parent species in case of fimbriatus-
catla hibrid. No information is available regarding the body measurements of carp hybrid at pro-larval stages except that of Maheswari et al. (1988) according to whom, catla-rohu hybrid grew better than both the parents during embryonic and larval development.

5.1.4 Post larval development

In all the four breeds studied, the yolk-sac was completely absorbed by the fourth day after hatching (termed as zero day old post-larvae) and mouth was well developed with thick lips. Similar observations have been reported in case of major carps (Chakrabarty and Murty, 1972), and their hybrids (Konda Reddy, 1977; Basavaraju, 1978; Gopal 1980).

The dorsal fin bud appeared in zero day old post-larvae of catla-fimbriatus 2 rays and fimbriatus-catla without rays, while it appeared in one day old post-larvae in case of fimbriatus. Separation of dorsal fin took place in two days old post-larvae of both hybrids and parent species. Mookarjee (1945) reported the appearance of dorsal fin rudiment in three days old major carps. According to Konda Reddy (1977), the dorsal fin in catla-rohu hybrid appeared in one day old post-larvae and had two rays, while the one day old post-larvae of rohu-catla hybrid did not have rays in the
The dorsal fin in rohu, mrigal and their hybrids appeared on 5th day after hatching (1 day old post-larvae) but it was not completely separated. In two days old post-larvae of these hybrids the dorsal fin was completely separated with six unbranched rays (Basavaraju, 1978).

Chakrabarty and Murty (1972) observed that the air-bladder in all the three major carps was constricted in two days old post-larvae. Similar observations have been made by Konda reddy (1977) in case of catla, rohu and their hybrids. In rohu and marigal-rohu hybrid, the constriction of air bladder took place in two days post-larvae, while the constriction of air-bladder was noticed only in three days old post-larvae (Basavaraju, 1978). In the present study constriction of air bladder took place in two days old post-larvae of catla, fibriatus and catla-fimbriatus while it was noticed in three days old post-larvae of fibriatus-catla hybrids.

In the present study, the pelvic fin bud appeared in zero day old post-larvae of catla-fimbriatus hybrid, while it appeared in three days post-larvae of fibriatus-catla hybrid. In case of catla and fibriatus it was noticed for the first time in zero day and one day old post-larvae respectively. Anal fin was noticed in one day old post-larvae of all the four breeds studied. Chakraborty and Murty
(1972) reported the appearance of anal and pelvic (ventral) fins in two days old post-larvae of major carps. Konda Reddy (1977) and Gopal (1980) also recorded the appearance of anal and pelvic fins in two days old post-larvae of catla, rohu, mrigal and their hybrids. The anal fin bud was seen in two days old post-larvae of rohu-mrigal and mrigal-rohu hybrids while the pelvic fin appeared in the three days old post-larvae (Basavaraju and Varghese, 1981, 1983) as noticed in the fimbriatus-catla hybrid in the present study.

One of the parents, catla does not have barbels while the other parent has a pair of barbels. The barbels appeared in eight days old post-larvae of fimbriatus, while a pair of rudimentary barbel were noticed in 16 days old post-larvae of both the hybrids. However, appearance of barbels were reported in seven days old post-larvae in case of catla-rohu, rohu-catla hybrids (Konda Reddy, 1977), rohu-mrigal and mrigal-rohu hybrids (Basavaraju and Varghese, 1981, 1983). The size of the barbels in the above hybrids was much shorter than fimbriatus. In the present study also barbels are very rudimentary and could be seen only under higher magnification.

In fimbriatus both the lips are fringed (the lower being thickly fringed), while they are not fringed in catla. Fringed nature of lips was first noticed in eight days old
pest-larvae of fimbriatus where lower lip was fringed and in 11 days: old post-larvae both the lips were clearly fringed. In case of both the hybrids only lower lip was moderately fringed and the fringed nature of lips was observed for the first time in eight days old post-larvae but could be clearly seen only in 11 days old post-larvae. In the case of catla- rohu and rohu-catla hybrids, only lower lip was fringed, exhibiting intermediate feature between the parent species and the fringed nature was noticed in eight days post-larvae. Basavaraju and Varghese (1981, 1983) also reported that only lower lip was fringed in rohu-mrigal and mrigal-rohu hybrids which was visible under higher magnification in 11 days old post-larvae. As observed by these authors, in the present study also, the hybrids show an intermediate feature in fringed nature of lips. Appearance of scale has shown wide variation in major carps and their hybrids. Khan (1943) stated that the scales appeared in 20 days old post-larvae, while Mookerjee (1945) observed the appearance of scales in 25 days old post-larvae of major carps. In catla-rohu and rohu-catla hybrids scales appeared in the opercular region in 11 days old post-larvae, while the entire body was covered by scales in 15 days old post-larvae (Konda Reddy, 1977). Whereas scales appeared in the pectoral region of 15 days old post-larvae of rohu-mrigal and mrigal-rohu hybrids
(Basavaraju, 1978). Similar observations have been made in catla-mrigal and mrigal-catla hybrids (Gopal, 1980). In present study, the scales were observed for the first time in 11 days old post-larvae of all the four breeds.

The caudal spot in catla is not prominent and does not take any particular shape, while it was almost triangular in fimbriatus. While the caudal spot was slightly triangular in catla-fimbriatus hybrid and was band-shaped in case of fimbriatus-catla hybrid. However, the caudal spot was intermediate to parental species in hybrids between catla and rohu (Konda Reddy, 1977) and between rohu and mrigal (Basavaraju, 1978).

Body measurements
From the analysis of variance test, it was found that all the body measurements with the exception of pre-dorsal length and length of dorsal fin base of four breeds were highly significant. However, there was no significant difference between the two hybrids.

The size (total length) attained by fimbriatus-catla hybrid at the end of larval development was more than both the parents, while it was intermediate between the parents in the reciprocal hybrid, catla-fimbriatus. Maheshwari et al. (1988) stated that catla-rohu hybrid grew faster than both the parents during larval development.
It could be inferred from the above that the development of the two hybrids was quite normal and followed the same trend that of parents with a few minor variations. The larvae of the hybrids exhibited intermediate nature in features by which the parents differ significantly.

Taxonomic characterisation

Morphometric or numerical and biochemical characters (especially the electrophoretic patterns) are the important direct methods used for distinguishing hybrids and parental species (Chevassus, 1983). Therefore, in the present study also, these methods were employed for finger printing the hybrids and parental species.

Morphometric and meristic studies

Morphological features

The studies on morphological features revealed that the two hybrids, catla-fimbriatus and fimbriatus-catla are very similar to each other with only minor variations and it is careful observations only it is possible to distinguish one from the other.
In *catla-fimbriatus* hybrid, body is deep, head smaller than *catla*, dorsal fin darker at the base and margins. The reciprocal hybrids also has small head, deep body but the fins are pinkish, especially in the margins. This shows that the coloration of fins is inherited from male parent as the fins in *catla* are darker, while both fins and scales are pigmented in *fimbriatus*. The anal fin is shorter in case of *fimbriatus-catla* than *catla-fimbriatus*. These minor morphological features may be of help to distinguish these hybrids in the field.

The mouth is slightly inferior and only the lower lips is moderately fringed in both the hybrids and and a pair of rudimentary barbels are present. Thus the hybrids have inherited characters from both the parents in respect of the position of mouth and nature of lips while, resemble *fimbriatus* in the presence of barbels. Similar observations have been reported in other carp hybrids (Desai and Rao, 1970; Tripati et al., 1974; Natarajan et al., 1976; Konda Reddy and Verghese, 1980; Basavaraju and Verghese, 1980a; Bhowmick et al., 1981; Choundar, 1985, 1986a, 1986b; Gopal et al., 1989).

**Morphometric characters**

The two hybrids studied showed varying features in morphometric ratios. In order to determine their similarity or otherwise to parent species, the data was subjected to multiple discriminant analysis which revealed that the *catla-fimbriatus* hybrid resembled more of female-parent in respect of morphometric ratio, length of head and height of head, while it leaned more towards male parents in ratios, total
length/standard length, least height of caudal peduncle, length of head and height of head. It has inherited from the parents characters like total length/height of body, total length / pre-dorsal length and total length least height of caudal peduncle. The rest of the characters were peculiar in that they showed no similarity to either of the parents. To summarise 21.43 per cent of the characters were inherited from both the parents, 21.43 per cent from male parents, 7.14 per cent from female parent and 50 per cent were peculiar, in that they were dissimilar to both the parents. In the reciprocal hybrid fimbriatus-catla, total length/fork length, total length / standard length, total length / pre-dorsal length length and length of head / length of head (28.57 %) were inherited from both the parents, while total length/maximum depth of body, total length / pre-anal length and head length / height of head (21.43 %) were inherited from female parent. The male characters were inherited in case of total length / least height of caudal peduncle and length of head / eye diameter (14.28 %). The rest of the characters (35.41 %) were dissimilar to that of parents.

Chondar (1985), while studying the systematics of rohu-catla hybrid, reported that about 25 per cent characters of the hybrid are intermediate between those of the parental species, 3.125 per cent and 9.40 per cent like those of rohu and catla respectively, 3.125 per cent common to both the parents and the rest (59.575 %) were peculiar, showing no similarity to either of the parents, while in the reciprocal hybrid, catla-rohu, as much as 50 per cent characters appeared to be drawn from both the parents, 11.76 per cent like catla, 5.90 per cent like rohu, 5.90 per cent similar to both the parents and the rest 26.47 per cent peculiar, showing dissimilarity to both the parents (Chondar, 1986a). In mrigal-rohu, 47.60 per cent characters were intermediate in nature, while 44.10 per cent were unlike either of the parents (1986b).
In hybridisation between major carps and common carp, the characters tend to lean more towards common carp as reported by Gupta et al. (1989) in mrigal-common carp, George and Reddy (1987) in common carp-rohu and Khan et al. (1989) in rohu-common carp. The above authors attributed this to the variation in chromosome numbers in the parents.

Male dominance was seen in case of the morphometric ratio, length of head /eye diameter in the hybrids studied presently. However, observations of Basavaraju and Varghese, (1980a) in rohu-mrigal and mrigal-rohu hybrids revealed the female dominance in respect of this character.

In the present study, the hybrids have combined the desirable characters of catla (deep body) and fimbriatus (small head). Similar observations were reported by Konda Reddy and Varhese (1980a), Bhowmick et al. (1981); Chondar (1985,1986a) in catla-rohu hybrids and Bhowmick et al. (1987) in calbasu-catla hybrid.

The two hybrids studied did not show any difference in their meristic characters except in case of number of rays in the caudal fin and in the number of lateral line scales. The number of caudal fin rays were intermediate in nature in catla-fimbriatus, while number of lateral line scales in fimbriatus -catla was same as that of fimbriatus. A
similar pattern was reported by Konda Reddy and Varghese (1980), Basavaraju and Varghese (1980a) and Gopal et al. (1989).

According to Lagler et al. (1962), hybrids in F1 generation exhibit characters that lie approximately intermediate between those by which the parent species differ significantly. In the present study also, the hybrids inherited characters from both the parents in those characters in which the parents differed significantly, such as depth of body, size of the head, nature of lips, position of mouth, while did not differ from the parents in characters in which the parents did not show significant difference like number of rays in the dorsal, ventral anal pelvic fins.

5.3.2 Electrophoretic studies

The electrophoretic data on protein and enzyme patterns is useful in distinguishing different species, strains and characterisation of hybrids. (Clayton and Gee, 1969; Whitt et al., 1973; Stanley et al., 1976; Mulley and Shearer, 1980; Heck et al., 1983; McAndrew and Majumdar, 1983; Sudharshana, 1983; Sudharshana et al., 1983; Mascaranas et al., 1986; DeSilva and Ranasinghe, 1989; Eknath et al. 1991).

The white muscle (Sarcoplasmic) protein patterns showed high homology indices among the two parents rather than serum
protein profiles. The homology of the two hybrids with the parents was similar and the two hybrids were indistinguishable with perfect homology. The results compare with that of Mascaranas et al. (1986) that, the protein profiles are not indicative of the differences in the two hybrids.

Further, while studying the intraspecific variations at the biochemical level haemoglobins and few tissue enzymes like LDH, ME, esterase and phosphatase were examined. The use of specific histochemical staining permits study of the activity of individual enzymes on the gels. The genetic variability among the different species, varieties or natural populations could be investigated by enzymatic analysis.

In the present study the LDH isozymes showed a tissue specific expression among the parent species, while the pattern was similar among the two hybrids showing expression characters of both the parents. Similar observations were reported by Beck et al. (1983) on F triploid hybrids of Ctenopharyngodon idella and Hypophthalmicthys nobilis that LDH genes of both parents were functional in the hybrids. The genes products of A and B express in all the tissues examined, while only the liver tissue expresses the C gene product (C4 isozyme) as also seen in other species of cyprinids (Klose et al., 1969; Whitt et al., 1969;
Sudharshana et al., 1983) and in members of the family gadidae (Odense et al., 1969; Shaklee and Whitt, 1981). Further, examination on differential LDH gene activity during development of fertilized eggs up to fingerling stage, showed that B gene (B isozyme) express early during embryonic stage and the A gene starts expressing at the hatchling stage. The C gene product could be detected at fry stage. The expression pattern of LDH-A, B and C genes was similar in both the parents as well as in the hybrids. Since the B gene of both the parents had similar anodal mobility, whether the maternal pattern expresses in early embryonic stages could not be concluded. The B of maternal parent are synthesized in oocytes and stored in early embryonic stages is well reported in Xenopus (Wall and Blacker, 1974; Vonwyl, 1983).

The parent haemoglobin were observed to express in the two hybrids, indicative of the expression of parent globin genes and malic enzyme loci in the hybrids. This corroborates with the earlier report that haemoglobin shows multiple bands and the hybrids was apparently summation of the parent fractions (Cross and O'Rourke, 1978; Beck et al., 1983). Whereas Khuda-Bukhsh et al. (1989) reported a species specific haemoglobin pattern in the two cyprinid parents (C. carpio and L. calbasu) and the haemoglobin pattern of the hybrid showed resemblance to the maternal parent.
In the present study three alleles of muscle ME, are expressed in both the parents and hybrids and the mobilities were similar. Hence, the hybrids show the complete expression of ME genes. On the contrary ME gene locus in fish has a very rare allelic variation as in case of salmonids and cyprinids (Salmenkova and Volokhonskaya, 1973).

The alpha and beta-esterases showed distinct species specific patterns. The liver esterases of the hybrids and their parents showed complex patterns, while the muscle esterase pattern of the two hybrids seems to be more towards the catla. But a clear cut expression was seen in serum patterns i.e., ACP-6 and ACP-7 are expressed in fimbriatus and catla respectively and the two bands are consistently expressed in both the hybrids. The serum estrase data again supports the finding that the hybrids gene pattern is the summation of the parents. Similar studies were reported by Child and Solomon (1977), Beck et al. (1983) and DeSilva and Ranasinghe (1989).

Acid phosphatase enzyme patterns which were species specific showed a similar banding pattern in the hybrids. Several new bands appeared to express in the hybrids.

In summary, electrophoretic analysis of selected proteins revealed that both the parental genomes were functional in the hybrids. Since LDH, ME, haemoglobin showed
similar electrophoretic mobility in the parents, other enzymes like esterase, phosphatase, etc., are more useful proteins for studying the gene expression in the hybrids. Further studies are required with several more suitable loci to examine the relationship between gene expression and genomic dosage.

Growth and feed utilization in hybrids and parent species under monoculture system

Growth

The study on comparative growth of catla-fimbriatus and fimbriatus-catla and their parents in monoculture revealed that both the hybrids grew much faster than the slow growing parent, fimbriatus and slightly slower than catla under identical conditions. Among the two hybrids, fimbriatus-catla exhibited faster growth than the reciprocal cross. Its growth was almost nearer to that of catla.

The growth pattern of all the four breeds showed similar trend in replicate tanks. It was observed that catla registered faster growth throughout the experimental period, while the least growth was observed in fimbriatus. The growth of two hybrids was almost same during the first month after which the growth of catral-fimbriatus was faster than reciprocal cross till 70th day after stocking and thereafter it was surpassed by fimbriatus-catla hybrid and
maintained that trend till the termination of the experiment. This fluctuation in growth could be attributed to the overlapping food habit of these hybrids in the early phase of development. Similar observation was by Bhowmick et al. (1981) in case of catla- rohu hybrids. As observed by many earlier workers (Chaudhuri, 1971; Konda Reddy, 1977; Gopal, 1980; Bhowmick et al., 1981, Varghese et al., 1984; Basavaraju et al., 1990) in the present study also the catla registered faster growth than fimbriatus and two hybrids, while the growth of fimbriatus was lowest. Manissery et al. (1986) also observed the slow growth of fimbriatus in cement tanks. David et al. (1974) reported that the fimbriatus can grow up to 400 g year. The two hybrids registered an intermediate growth rate between the parent species.

The results of analysis of variance test also revealed that the weight gained by four breeds was significantly different between four breeds. The weight gain between fimbriatus - catla and catla did not differ significantly indicating that the growth of these two breeds was almost same, while there was significant difference in weight gain between other breeds.
Except for the present study, no detailed information is available on growth performance of these hybrids either in comparison with their parental species or with other hybrids, although *catla-fimbriatus* hybrid was produced in 1963 (Anon., 1963). Hence, the growth performance of these hybrids have been discussed in context with other carp hybrids.

Several interspecific and intergeneric hybrids have been produced among cultivable species of carps and varying results have been reported on their growth performance. A review of earlier works indicate that the hybridisation involving *catla* appear to result in production of $F_1$ hybrids with promising results (Chaudhuri, 1959; FAO, 1971b; Chaudhuri, 1971, 1973; Makeyeva, 1975, Ibrahim 1977; Gopal, 1980, Konda Reddy and Varghese, 1980; Bhowmick et al., 1981; Varghese et al., 1984; Bhowmick et al., 1987; Maheshwari et al. 1988, 1990). Similar observation were also recorded during the present study.

The hybrid between male *catla* and female *rohu* (*catla-rohu*) was found to grow faster than *rohu* (Anon., 1970; Konda Reddy 1977) and nearly as fast as *catla* (Chaudhuri, 1973; Varghese et al., 1978). Jhingran (1975) was also opined that *catla-rohu* hybrid was the most promising among Indian-major carp hybrids.

The growth in terms of length also indicated a pattern similar to that of weight.

Chevassus (1983) opined that, inspite of old assertions on their obvious superiority (Skinner, 1938), the growth of hybrids mostly appear to be intermediate between that of the parent species in most groups of fishes. The faster growing parent transmits atleast
partially this potential to hybrids [Suzuki and Fucuda (1972) in salmonids and Burtzer and Serebryakov (1973) in asciipenserids].

Varying results have been reported with regard to growth performance of rohu-catla hybrid. According to Alikunhi et al. (1971), rohu-catla hybrid showed better growth than catla, while Varghese and Sukumaran (1971) reported that it grew faster than both the parents. However, according to Konda Reddy (1977) the growth rate of rohu-catla hybrid was slower than both the parents but they assigned no reasons for this phenomenon. The growth of catla-rohu hybrid, during embryonic and larval development was faster than rohu and almost equal to catla Maheshwari et al. while it grew 30 to 38 per cent more than rohu in ponds, small and large reservoirs (Maheshwari et al., 1990).

Bhowmick et al. (1987) observed that the catla-calbasu hybrid grew faster than calbasu. The growth of catla-mrigal was superior to mrigal and mrigal-catla in monoculture (Gopal, 1980). Varghese and Shantaram (1979), while evaluating comparative growth of three major carp hybrids, namely, catla-rohu, mrigal-catla and mrigal-rohu found that the catla-rohu was the fastest growing, followed by mrigal-catla and mrigal-rohu, in that order.

Basavaraju and Varghese (1980b) reported that the growth of rohu-mrigal rohu hybrids was inferior to both the parents. Khan et al. (1989) also reported that the growth of rohu-common carp was slower than parents. The growth rate of rohu-fimbriatus hybrid was 37.4 per cent faster than
fimbriatus but 30.4 per cent slower than rohu (Basavaraju et al. 1990).

From the foregoing account it is seen that the growth rate in most cases is intermediate between the parental species. Although fimbriatus, is the slow growing carp, the growth of hybrids was faster than fimbriatus, probably due to the influence of fast growing parent, catla which might have transmitted this potential to hybrids as opined by Suzuki and Frukuda (1972) and Burtzer and Sarebryayakov (1973). The results of the present study on growth are in agreement with those of Lagler et al. (1972) in that catla is the fastest growing carp while, fimbriatus is slow growing mediumn carp and hence, the hybrids have acquired an intermediate characters to those of parental species.

Water quality

Knowledge of water quality is extremely important in aquaculture. Nearly every problem that arises in an aquaculture system is the result of or leads to degradation of water quality (Stickney, 1979). It is imperative to understand the complex interactions that take place continuously between ecosystem and the organism living to increase survival and maximise production through manipulation of ecosystem. Hence, the water quality management has become an integral part of aquaculture.
The Indian carps thrive well in a water temperature of 18.0 to 37.0 °C (Jhingran and Pullin, 1988; Jhingran, 1988), while a temperature of 25 to 35 °C has been reported to be optimum for their culture (Anon., 1988). The maximum temperature recorded during the study was 34 °C and the minimum 21 °C. These values are within the recommended range of water temperature for warm water fishes (Byod and Lichtikoppler, 1979; Anon., 1988) and hence, it is presumed that temperature was not a limiting factor for the growth of fishes.

The level of dissolved oxygen present in water is among the most important factors in aquaculture (Boyd, 1989). If a sufficient level of dissolved oxygen is not maintained, fish will be put to stress, make them vulnerable to disease and parasitic outbreaks and/or growth rate and food conversion efficiency will suffer (Stickney, 1979). As a general rule, if dissolved oxygen is equal to or excess of 5 mg l⁻¹, no stress will be placed on aquaculture organisms (Wheaton, 1977). According to Huet (1975), the optimum level for cyprinids should be 6 to 7 mg l⁻¹, but temporarily it can go down to 3 mg l⁻¹. Since the dissolved oxygen ranged between 4.13 mg l⁻¹ (only on one occasion) during the experimental period, no adverse effect of dissolved oxygen on the growth and survival of fish could be attributed to this factor.
Another important index of water quality in fish ponds is the hydrogen ion concentration (pH). Slightly alkaline water with pH 7.0 to 8.0 is regarded as suitable for fish life (Hora and Pillay, 1962). Swingle (1967a) stated that water having a pH range of 6.5 to 9.0 are most suitable for pond culture. The alkaline pH values of 6.8 to 8.8 recorded during the study are within the range of recommended levels.

The free carbon dioxide content during the experimental period was in the range of zero to 2.8 mg l⁻¹. These values were found within the recommended levels of less than 5.00 mg l⁻¹ for fish life (Boyd and Lichtkoppler, 1979). The absence or very low levels of free carbon dioxide could be correlated to the fact that appreciably high concentration of dissolved oxygen and the presence of plankton blooms which use carbon dioxide for photosynthesis.

The capacity of a water body to resist changes in pH can be measured by alkalinity. In aquaculture system, the alkalinity should generally be between 30 and 200 mg l⁻¹ in fresh waters (Stieckney, 1979). Schaperclaus (1963), regarded alkalinity of 200 to 500 mg l⁻¹ of calcium carbonate as most productive. Alikunhi (1957) considered water having alkalinity more than 100 mg l⁻¹ as highly productive. Hence, the alkalinity values of 102 to 330 l⁻¹ recorded in the present experiment are to be in the optimum range (Anon.,
1988). These values were also optimum from the view point of reduced carbon dioxide in water and lesser fluctuation in pH values which are associated with buffering activity (Stickney, 1979; Boyd and Lichtcoppler, 1979).

Plankton

Plankton form the source of endogenous nutrients in fertilized pond culture system and will have a greater impact on fish growth and production. The fish involved in the present experiment are planktophagous in nature.

The mean wet weight of plankton during the present study varied from 50 mg 50^-1 to 760 mg 50^-1, the weight varied between 10 and 56.67 mg 50^-1. The mean phytoplankton number ranged from 265 to 10,933 units 1^-1 and the zooplankton varied between 54 to 1,831 units 1^-1. These values appear to be in the recommended range of levels (Ramesha, 1992). The plankton was less in the inter half of the experimental period. This could be attributed to intensive growing of plankton by the fishes.

In the experimental cisterns, zooplankton was dominated by cladocerans, rotifers, and copepods. The phytoplankton was represented by chlorophyceae, cyanophycose and Bacillariophyceae. The data on plankton indicated that sufficient plankton was available for fishes for their nutrition.
Feed utilisation

Food conversion ratio (FCR) and food conversion efficiency (FCE) are the two indices used for measuring food utilisation efficiency of fish. The best conversion efficiency was seen in case of fimbriatus-catla, catla, catla-fimbriatus and fimbriatus in that order. It was almost same in case of catla and fimbriatus-catla, which reflected in terms of growth. The statistical analyses confirmed that there is no significant difference between catla and fimbriatus-catla in terms of weight gain which indicate that the fimbriatus-catla hybrid has combined the fast growth and better food conversion efficiency of catla. No earlier studies are available for comparison of these hybrids with other hybrids.

Growth, production and contribution of hybrids to fish production

The growth of hybrids in multispecies culture was similar to that of growth under monoculture experiment. Fimbriatus-catla hybrid grew faster than the reciprocal hybrid and mrigal, but slower than catla and rohu. The slow growth rate might be due to slight overlapping in food habits of rohu and hybrids. Similar observations were made by Gopal et al. (1989) in case of catla-mrigal and mrigal-catla hybrids. When grown along with other fishes, both
the hybrids proved inferior and attributed it to the common feeding habit of the hybrids and mrigal. Varghese and Shantaram (1979) found that of the hybrids of three major carp, the growth of catla-rohu was the best followed by mrigal-catla and mrigal-rohu. Varghese et al. (1984) while assessing the performance of catla-rohu and catla-mrigal hybrids in composite fish culture involving catla, rohu and mrigal, reported that catla-rohu was clearly superior to rohu, in that it attained higher individual weight. While the performance of the mrigal-catla hybrid was dismal.

The total fish production in the present study was higher in the presence of hybrids, which probably suggests that hybrids do not affect the growth of other fishes. Among different species, catla contributed maximum to total fish production followed by rohu, fimbriatus-catla, mrigal and catla-fimbriatus hybrid. The contribution of hybrids put together was next only to catla. This seems to indicate that the fimbriatus-catla is of considerable potential and can be considered as a candidate in multispecies culture. However, further studies are warranted before any definite conclusion could be arrived at.

The water quality and plankton abundance in the experiments were within the recommended levels and thus were not limiting factors for survival and growth of fish.
Meat yield

One of the objective of the present study viz., to explore the possibility of combining the small head of fimbriatus and deep body of catla in the F hybrids has been met with success. The head of both the hybrids was much smaller than that of catla and body deep as that of catla. The percentage of meat yield was higher in both the hybrids than the parental species which was statistically significant. The flesh yield was lowest (52.53 %) in catla, 61.89 per cent in fimbriatus, 62.10 and 63.74 per cent in catla-fimbriatus and fimbriatus -catla respectively. Such reports of high meat yielding hybrids have reported by Chaudhuri et al. (1975) and in catla-calbasu, Bhowmick et al. (1981) in catla-rohu; Bhowmick et al. (1981) in calbasu-catla; Khan et al. (1988) in common carp-rohu, common carp - catla and common carp-rohu and Khan et al. (1989) in rohu-common carp.

Relative heterosis calculated to find out the percentage increase /decrease of meat yield of hybrids over parents indicated an increase of 11.40 per cent in fimbriatus -catla and 8.54 per cent in catla-fimbriatus over midparents. When compared to better parent (fimbriatus ), the heterobeltiosis showed an increase 0.33 per cent for catla-fimbriatus and 11.40 per cent for fimbriatus-catla hybrid. This indicates that the hybrid vigour is manifested in the form of meat yield in these F hybrids.
Food of hybrids under pond rearing system

Food habit of fishes depend on its mouth position, the ecological niche they occupy and their age. Generally food and feeding habits of fishes caught from natural waters are analysed. Since the hybrids were evaluated from culture point of view, their gut contents were analysed to determine their food habits under pond rearing system. Of the parents species involved, catla is known to feed on zooplankton and fimbriatus (which occupies lower ecological niche) subsists on algae (belonging to chlorophyceae and Bacillorophyceae), macrovegetation and decaying organic matter (Jihngran, 1975). In the present study, zooplankton dominated the gut of catla, while the algal matter, detritus and semidigested matter were the main food item of fimbriatus. The food of hybrids was both zooplankton and phytoplankton indicating that they have inherited the characters from both the parents. Bhowmick et al. (1987) stated that the hybrid calbasu-catla inherited the food habits from both the parents. Catla-rohu hybrid was mainly phytophagous with much wider spectrum of food preference (Desai, 1970; Natarajan et al., 1976; Bhowmick et al., 1981). According to Khan et al. (1989) that the food of hybrids between catla and mrigal was similar to that of mrigal.
Body carcas composition

Factors such as geographical location, season, sex, age, species and food can effect the body composition of a fish (Jafri et al., 1964; Khawaja, 1966). In the present study the chemical composition of flesh did not vary significantly between the hybrids and parental species. There are no published reports on the chemical composition of flesh of carp hybrids and hence, the present data could not be compared.

The hybrids produced are intermediate in most of the characters like, embryonic and larval development, important taxonomic characters and growth and were superior to both the parents in meat yield. They have combined the desirable qualities from both the parental species. Chevassus (1983) stated that the hybrids can be of economic value when it appears as a compromise between parents having different desirable character (between a fast growing species and a more hardy and slow growing one). The hybrids produced in the present study have combined the fast growth of catla, small head of fiberatus with high meat yield. Hence, they are of considerable importance and warranted attention from aquaculture point of view.