

REVIEW ON THE HYBRIDIZATION OF CULTURABLE CARPS



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REVIEW ON THE HYBRIDIZATION OF CULTURABLE CARPS

A Thesis

By

Farhana Taslima

Examination Roll No. MS-040609

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**A thesis submitted in partial fulfillment of the requirements
For the Degree of Masters of Science in Fisheries and Marine Resource
Technology**



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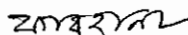
Khulna University

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Declaration

Review on the hybridization of culturable carps

The results presented in the thesis with the above mentioned title are entirely of the candidate's own investigations and no part of the results has been accepted for any degree nor is it being concurrently submitted for any degree.



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Abstract

The study on review on hybridization of culturable carp was conducted with the help of different books, journals, literature, thesis papers, technical papers, references, secondary data, internet etc. The goals of this study were to make overall scenery of hybridization of culturable carp in the world. Genetics is new discipline of science and fish genetics is more so. By properly utilizing the knowledge of hybridization a revolutionary change in aquaculture is possible. At the same time lack of knowledge in utilizing this sector can bring dangerous harm to the nature. In different part of the world fish hybridization technique is used with numerous problems. Further research is necessary for the development of culturable carp hybridization technique.

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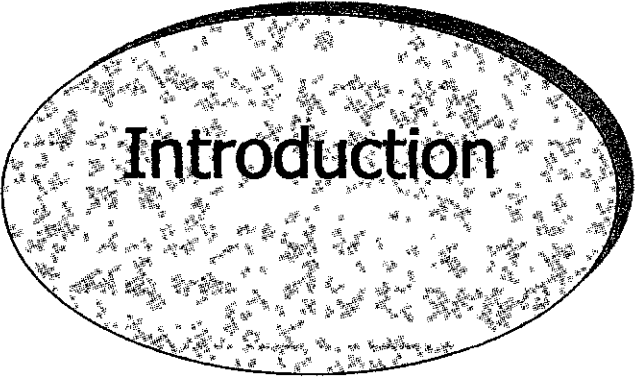
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CHAPTER 1



Introduction

Chapter 1

Introduction

1.1. Background of the study

Hybridization is the mating of genetically differentiated individuals or groups and may involve crossing individuals within a species (also known as line crossing or strain crossing) or crossing individuals between separate species. According to Tave (1993), interbreeding of two good species is denoted as hybridization.

Hybridization has become a common practice in fish culture, though it has not yet attained its rightful place in this branch of economy. The hybridization of fish for practical purpose has demonstrated its economic value. One may ask why hybrids should be created when excellent non-hybrids forms, are available. Hybrids are offered along with the pure species and not as substitutes. Preferences for hybrids are based on inherent characteristics of hybrid heterosis (hybrid vigour), which manifest as intensive growth rate, higher viability, adaptive flexibility, and some times early sexual maturation.

Charles Darwin attached great significance to hybridization: "If we do not take it for granted, at least we shall consider it highly probable - the existence of a great law in nature, the law of crossing animals and plants which are not closely related to each other and this is extremely useful and even necessary".

This breeding technique is used by aquaculturists in the hope of producing aquatic organisms with desired traits. Commonly the desired goal is to produce offspring that perform better than both parental species. Hybridization may also be used to transfer

other desirable characteristics from one group or species to another, to combine valuable traits from two species into a single group, and to produce sterile individuals. However, it is a quick and not a very dignified way in the sense that it is a hit or miss proposition being based on fortuitous combination of alleles in zygote producing dominant effect.

Any efforts for improvement of production traits in fish require exploitation of genetic variation Tave (1993). Genetic variation has three sub components, Additive genetic variance (V_A), Dominance genetic variance (V_D) and Epistatic genetic variance (V_I). When little or no V_A exists and it is either difficult or impossible to improve a phenotype by selection, the breeding technique that can be used to improve productivity is hybridization. Hybridization improves productivity by exploiting V_D . Hybridization can be used even when a large amount of V_A exists.

V_D is the genetic variance produced by the interaction of alleles at each locus. Because this form of genetic variance depends on interactions, it is disrupted during meiosis and cannot be transmitted from a parent to its offspring. Dominance genetic variance is created anew and in different combinations each generation and its effects are basically those based on luck. Fish that are superior because of certain interactions are superior result from fortuitous combinations of alleles. Unfortunately these fish cannot transmit their superiority to their progeny. Consequently, the goal in a crossbreeding program is to discover which combination of parents produces the combination of alleles that produces the desirable interaction in the progeny and thus improves productivity.

V_A and V_D are diametrically opposed; consequently, selection and crossbreeding are also diametrically opposed. In selection animals are chosen based on individual or family

merit in the hope that the next generation will closely approximate those have chosen. In crossbreeding, the next generation does not have to approximate the brooders and the cross was made previously, one cannot predict the outcome of a mating to produce F_1 hybrids. The production of superior F_1 hybrids is a hit-or-miss proposition. One can mate two superior fish and produce nothing but culls or one can mate two culls and produce a grand champion. Basically, what someone is trying to do is to discover a cross that nicks (produces superior hybrid progeny). When right combination is found, it can be crossed to improve productivity.

Hybridization in fish is relatively easy, and the variety of species crosses and even wider taxonomic combination is vast. List of such hybrids occurring naturally and/or produced artificially have been published by Slastenenko (1957). Tave (1993) described some general use of hybridization. Some indications of the use of hybrids are found to generate genetic variance, to assess the genetics of sex determination, to improve productivity etc. Hybridization can be incorporated into a selection program as a final step to produce animals and plants for grow out. In this case, fish are selected in two lines to produce good hybrids; after the selection program selected lines are hybridized. Another use of hybridization is found for the production of new breeds or strains. Hybridization can also be used to produce uniform products. Processing plants and consumers often desire uniform products, and hybridization is the most efficient method of producing uniform progeny. Production of monosex population can be accomplished by hybridization. Hybridization is also effectively used for the production of hybrid to be stocked in natural water bodies that are unable to maintain self-reproducing populations. And this is done for research purpose. Hybridization can also be used in the production of gynogen, androgen, triploid, tetraploid progeny.

There are many examples, which show that hybridization plays an important role to improve productivity. Guidice (1966) finds that some hybrids improve yield by 10-18%. He also finds that hybridization improve seinability and food conversion. Hickling (1960) shows the most famous and most important example of production of monosex population by hybridization. He produces all males of tilapia. Hybridization has been used to improve fishing success in put and take situation. Hybrids can also be used to improve a wild fishery. Wohlfarth *et al*, (1963) outlines program in which hatchery strain can be stocked to hybridize with local population in order to produce faster growing hybrids that can be harvested by commercial fisherman.

Hybridization, as a method of fish improvement, can be applied in many ways. This method is specially demanding in population which has undergone inbreeding depression and which has a little or no V_A left for it to be subjected to selective breeding and improvement. In this sense considering a presumed low level of genetic variations remaining in the hatchery managed brood, interspecific or intergeneric hybridization can be performed in the culturable species of carp. Interspecific crosses can often bring good gain in production and it means different (localized) hatchery stocks of the same species can be bred for the production of heterosis. In this case all different types of cross breeding can be practiced in case of culturable carps (Islam and Shah, 2007).

The article focuses on the hybridization and the discussion will be limited to the species of cultured carp.

Carps, which are the oldest cultivated fish, are also the most important cultured fish in the world. Due to their fast growing nature and taste, carps enjoy a prime position in the world aquaculture scenerios. Cultured carps can be classified into the following:

- Indian Major Carp
- Chinese Carp
- Common Carp
- Other carp

Although the Chinese and the Indian carps have been cultured in ponds for thousands of years, these fishes have not got domesticated, and differ very little from their wild ancestors. The Indian and Chinese carps do not reproduce in ponds, and this inability to breed under captivity has restricted attempts at selective breeding and hybridization of these fishes (Chaudhuri and Alikunhi, 1957)

The major carps of India fall under three genera, *Catla*, *Labeo* and *Cirrhinus*. Under the genus *Catla*, the species *C. catla*, under the genus *Labeo* fall the species *L. rohita*, *L. calbasu*, *L. fimbriatus*, *L. bata*, *L. gonius* and under the genus *Cirrhinus* fall the species *Cirrhinus mrigala*, *C. reba*, *C. cirrhosa*. Interspecific hybridization work has been carried out between the species of the genus *Labeo* and intergeneric hybridization between the species of the above mention three genera.

Chinese carp include the grass carp, *Ctenopharyngodon idella*; the silver carp, *Hypophthalmichthys molitrix* and the bighead carp, *Aristichthys nobilis*.

The common carp has four subspecies (Kirpichnikov 1967), Vis. *Cyprinus carpio carpio* of the European Transcaucasian area; *Cyprinus carpio aralensis* of the mid-Asian region; *Cyprinus carpio haematopterus* of the Amur-Chinese or Far Eastern region and *Cyprinus carpio viridivio-laceus* of North Vietnam.

There are numerous varieties and sub varieties or strains of common carp. The well-known variety of the Kwantung and Kwangsi regions of China is the “big belly carp” and of the Yangtze region, the “long bodied carp”. The well-known Indonesian orange-colored carp (*Cyprinus carpio* var. *flavipinnis*) has been split into a number of subvarieties, such as the lemon-colored Sinyonya and the gold brown Katjera Domas. There is also the green variety in Indonesia, the “Punten carp” with genetic traits, which are believed to be stabilized. The “Majalayan” Strain of West Java is also a greenish variety. The mirror carp (*cyprinus carpio* var. *specularis*) of the Galician variety or of the Franconian variety were transplanted into Indonesia in the first half of the 20th century and are distinct from the Aischgrunder (Germany) or Royale (France) varieties. The Russian mirror carp (*Cyprinus carpio* var. *specularis*) is now split into two varieties, the scale carp (*Cyprinus carpio* var. *communis*) and the leather carp (*Cyprinus carpio* var. *undus*). The other varieties of common carp are the Japanese races, which go by the name of Asagi and Yamato; Ropsha and Kursk of USSR; Dinnyes of Hungary and Nasice of Yugoslavia.



1.2. Problem statement

Fish genetics is a new discipline of science. Examples of genetical manipulations for improvement of fish are not many in the world. Though carp hybridization has got emphasis, as it has been the subject of different biological studies, sufficient information was not available.

1.3. Hypothesis setting

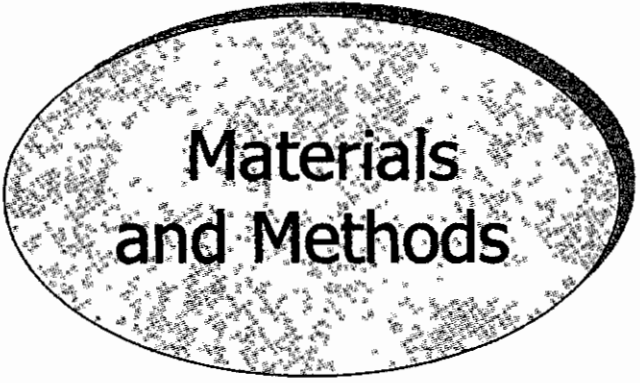
The study was mainly conducted to know about the hybridization of the culturable carps in the world. For this purpose different books, journals, thesis papers, technical papers etc

were used. It was thought that overall scenery of the hybridization of the culturable carps in the world would be obtained.

1.4. Objective of the study

- To know the present status of hybridization of culturable carp.
- To find potential area of hybridization, through research this can play a great role in world aquaculture.

CHAPTER = 2



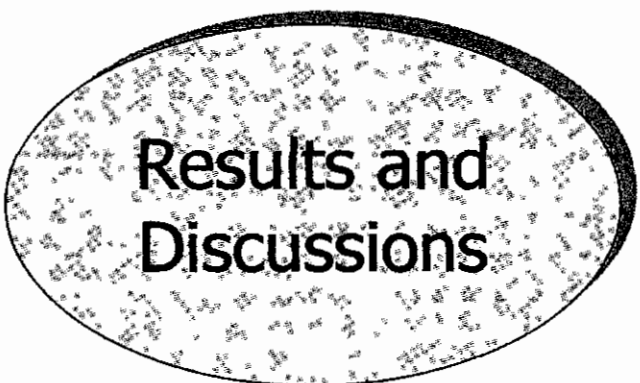
Materials
and Methods

Chapter 2

Materials and Methods

The informations of this review were collected from different sources. Different books, journals, literature, thesis papers, technical papers, references seminar, symposium reports were used for collecting data. Informations were collected through internet search. Some information was also collected from seminar library of Khulna University, Khulna, Bangladesh.

C H A P T E R = 3



**Results and
Discussions**

Chapter 3

Results and Discussion

Effort have been made to extensively search for the available literature on the hybridization of culturable carps in the world. The search obtained a few different types as follows

3.1. According to Tave (1993) there are four types of crossbreeding programs.

- Two breed cross
- Top cross
- Back cross
- Triple cross

3.1.1. Two breed cross

The most common is the two breed cross. Here two breeds, species, are hybridized to produce F_1 hybrids for grow-out.

A X B

↓

AB F_1 hybrids

The production of the F_1 hybrids is a terminal cross. One seldom wants to incorporate hybridization into a line that is undergoing selection because it will undo some of ones work on the exploitation of V_A . Basically, what one is trying to do is exploit V_D . This is the crossbreeding program that has been used in most fish hybridization studies. If one hybridizes two lines that have undergone selection, one will exploit both V_A and V_D .

3.1.2. Top cross

Top crossing is a variation on the two-breed cross in which an inbred line is mated to a non inbred line or strain. Some top crossed fish grew faster than parental lines (Ibrahim, 1977).

3.1.3. Back cross and triple cross

Backcrossing is another type of hybridization. Here the F_1 hybrid is mated back to one of its parents or parental lines. This is done to produce a hybrid with a greater percentage of one group.

A X B

↓

AB F_1 hybrids

AB F_1 hybrids X A

↓

AB-A backcross hybrid

The genome of the AB-A backcross hybrid is 75% A and 25% B.

This technique can be used to transfer desirable alleles from one strain or species to another. This technique can also be used to improve growth by exploiting maternal heterosis. To do these hybrids female are backcrossed to parental strain males.

A number of backcross hybrids have been produced and studied among the hybrids of Indian major carps by crossing the hybrid females with normal males of parent species.

The kalbasu-mrigal hybrid has been backcrossed with the normal males of *Labeo calbasu* and mrigal resulting in kalbasu-mrigal-kalbasu and kalbasu-mrigal-mrigal backcrossed hybrids. Similarly, kalbasu-rohu hybrid female has been backcrossed by the normal male of *Labeo calbasu* producing kalbasu-rohu-kalbasu hybrid (Ibrahim, 1977). The backcross hybrid kalbasu-rohu-kalbasu exhibited a high percentage of fertilization reaching over 98%. The hybrid possessed ventral mouth with a fringed lower lip and two pairs of barbels. The color of the hybrid resembled that of kalbasu. The yearlings of these hybrids (adults) were characterized by a smaller head and deeper body. In overall appearance, this back-crossed hybrid showed a close resemblance to kalbasu (Chaudhuri, 1971). Again rohu-catla female hybrid has been backcrossed with the normal male of *Labeo rohita* resulting in rohu-catla-rohu hybrid.

Triple cross is also called three breed cross. A three breed cross is used to produce various combinations of three different groups.

	%A	%B	%C
A X B			
↓			
AB F ₁ hybrids	50	50	0
AB F ₁ hybrids X C			
↓			
ABC F ₂ hybrids	25	25	50
ABC F ₂ hybrids X A			
↓			
ABC-A F ₃ hybrids	62.5	12.5	12.5

Two triple-cross hybrids have also been produced by crossing the female hybrid of kalbasu-mrigal with the male of *C. catla* thus resulting in kalbasu-mrigal-catla and the female hybrid of kalbasu-rohu with the male of *Cyprinus carpio* giving rise to the kalbasu-rohu-*Cyprinus carpio*.

When one group is brought back (A was brought back and mated to the F₂ hybrid in the above example), the program is also called a rotational cross. List of back-cross and triple-cross hybrids have been given in Table 1.

Table 1: List of backcross and triple-cross hybrids (Chaudhuri, 1971)

FEMALE	MALE	HYBRID	COMMENTS
1. Kalbasu-mrigal	x <i>L. Kalbasu</i>	kalbasu-mrigal-kalbasu	Hybrid cross has shown good percentage of fertilization. The hybrids could be reared to adult size. No further information available.
2. Kalbasu-mrigal	x <i>C. mrigala</i>	kalbasu-mrigal-mrigal	Hybrid cross has shown good percentage of fertilization. The hybrids could be reared to adult size.

		No further information available.
3. Kalbasu-rohu x <i>L. Kalbasu</i>	kalbasu-rohu-kalbasu	Hybrid cross has shown higher fertilization (98%). Hybrids more resembled the kalbasu.
4. Rohu-catla x <i>L. rohita</i>	Rohu-catla-rohu 	Hybrid cross has shown good percentage of fertilization. The hybrid cross resulted in five different phenotypes with regard to body shape and color.
5. Kalbasu-mrigal x <i>C. catla</i>	kalbasu-mrigal-catla	Fertilization in the hybrid was normal (70-80%). No other details available (needs further study)
6. Kalbasu-rohu x <i>C. carpio</i>	kalbasu-rohu-common carp	No details are available. (needs

		further study)
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3.2. Purdon (1983) classified hybridization into two categories namely;

- Natural hybridization and
- Artificial hybridization

3.2.1. Natural Hybridization

Several reports have been found on the occurrence of fish hybrids in nature from time to time. The classical review of this subject by Hubbs (1955) was based on his lifetime study on hybridization. Slastenenko (1957) has given a list of natural hybrids of the world, which suggests that species belonging to the cyprinid group are more prone to interbreed than other groups of fishes and Indian major carps belong to this group.

The importance of natural hybridization lies not so much in its positive implications for fish breeding - although as the artificial production of hybrids is a powerful tool in fish culture -but more in its implications for evolutionary relationships. Hybridization in the natural environment is more relevant today as an environmental issue in the sense that introduced or exotic species might interbreed with and upset the natural genetics of native populations of fish (Purdon, 1983).

Most of the basic features of hybrids, as accepted today were covered in Carl Hubbs (1955) review but hybrid inviability, the normal outcome of interspecific crossbreeding, was not considered fully. The main characteristics covered by Hubbs were (i) the

taxonomic relatedness of putative hybrid parents, (ii) the intermediacy of hybrids, with respect to those features which distinguished the parents, (iii) the enhanced performance of some hybrids described as heterosis (now sometimes euheterosis) but, more logically luxuriance and (iv) the sterility. According to Hubbs (1955) hybridization of fishes in nature largely comes about through environmental changes, particularly instability, or through imbalances between the species with or without the intervention of Man. A second major theme which runs through much of the earlier work, and is of great importance still, is the problem of introgression, i. e. the extent to which F₁ hybrids can join in subsequent reproduction so as to "mix" the genes of two species (Hubbs, 1955).

The normal hybrid situation in nature is that only F₁ hybrids are found; this is taken as evidence of hybrid sterility and a lack of introgressive hybridization (Hubbs, 1955).

Hybridization as natural occurrence of both interspecific and intergeneric hybrids of Indian major carps has been reported mostly from reservoirs. Occurrence of rohu-catla hybrid has been reported from the perennial irrigation tanks (reservoirs) in the state of Madhya Pradesh in India. A detailed study of the taxonomic characters of this hybrid has been made by Desai and Rao (1970). Occurrence of catla-rohu hybrids has been reported from Adhartal Lake also in Madhya Pradesh. On the basis of the morphological characters and position of the pectoral and anal fins, the parental species of these putative hybrids have been identified as female catla and male rohu (Tripathi *et al.*, 1974). Natural hybrids of similar type have been also reported by Natarajan *et al.* (1976) from the Rehand reservoir in the state of Uttar Pradesh.

Occurrence of carp hybrids like *Labeo fimbriatus* (Bl) x *L. gonius* (Ham.) and *L. calbasu* x *C. catla* in Rangwan reservoir in Uttar Pradesh has been reported by Prasad (1976). He

suggested that these hybrids form good substitutes for *L. gonius* and *L. calbasu* in reservoirs. Similarly, the hybrids of catla-rohu and rohu-catla would also form a good substitute for rohu in reservoirs (Natarajan *et al.*, 1976).

In "bundh" breeding occurrence of natural hybrids may be due to congestion in the spawning ground. Because of the limited space, there is very likelihood of ova of one species getting accidentally fertilized by the sperm of another species particularly in the case of Indian major carps with very compatible genomic structure. It is all the more easy and frequent to encounter natural hybrids when bred together in a relatively congregated condition (Zhang and Reddy, 1991).

3.2.2. Artificial Hybridization

Amongst animals, fish are very well suited to this approach and a vast literature exists on artificial hybridization, even greater than that we have already touched on with natural hybridization. Moreover, the scale and range of the studies in artificial hybridization is very wider than that for natural events (C E., Purdon, 1983).

Hybridization is an experimental tool for the measurement of linkage relationship. It's a more broadly based methodology in fish developmental genetics. Many scientists in different time studied developmental genetics through hybridization. Artificial hybridization make possible to produce fertile hybrids of two species, which do not cross in nature due to marked ecological differences. There are more chances of producing completely fertile hybrids if the species crossed have equal chromosome number, which must be homologous and able to conjugate in the course of gametogenesis. When there is unequal chromosome number and violation of the conjugation process, sterility occurs in

various degrees. Knowledge on chromosome complexes of the species will permit prediction with a greater degree of probability as to whether or not the hybrids will be fertile or sterile, and will avoid waste of labour and money.

FAO fisheries technical paper suggested for any genetic improvement programme to breed the candidate species artificially under controlled conditions. Soon after the success of induced breeding of the Indian major carps, work on genetic improvement of these carps was initiated in the late fifties starting with simple interspecific and intergeneric hybridization to produce and evaluate their useful traits for aquaculture, since hybridization was regarded to be one of the methods for combining desirable traits of selected species. Accordingly, hybridization work was carried out between different species of a genus (interspecific) and species of different genera (intergeneric) among the Indian major carps and Indian and Chinese major carps, including the common carp (*Cyprinus carpio* variety *communis*, Linnaeus,) to study whether the hybrids acquired any useful traits from their respective parent species.

There are four basic ways of achieving artificial hybridization:

- The most natural way is the simple cohabitation in captivity of males of one species and female of other. This is usual way for aquarium species to be crossed, but pond or farm fish can also be brought to succesful spawning with this approach. In one sense, this method is very close to natural hybridization brought on following introduction of a new species into the habitat of another.
- A further development of natural cohabitation is to use hormone stimulated sexual maturation: this can be achieved with pure hormones but is usually done by

injection of the fish with extracts of pituitary gland, often on an empirical basis.

The method is suitable for erratic or unreliable spawners.

It is the most commonly adopted technique of induced breeding. It is also called hypophysation technique. Success in this method was attained in 1957 (Chaudhuri and Alikunhi, 1957) and experiments in hybridization of Indian carps was initiated in 1958 by artificial fertilization of the stripped eggs of an injected female of one species by the sperms of an injected male of another species (Chaudhuri, 1960). Subsequent attempts were made to hybridize important species of Chinese carps and also the Indian × Chinese carps (Alikunhi *et al.*, 1963).

- Artificial fertilization, whereby eggs and milt are hand stripped from the fish for mixture, is the most practical way of producing hybrids or, indeed, producing any genetic crosses. It is widely practiced with many fish species. Finally, the fish may need stimulation by pituitary gland extract prior to hand stripping because of their extensive migrations upstream, may be caught before the natural period for ovulation and spermiogenesis.
- Much of the effort put into the hybridizing of fish has been merely to satisfy curiosity. This is often overlaid with specific aims, such as to produce bigger or better fish, but usually with little prediction of what might happen. It is probably true to say that whenever two or more species are held together in captivity, they will sooner or later be used for hybridization.

3.3. In culturable carp the following types of hybridizations are found:

- Intraspecific hybridization
- Interspecific hybridization
- Intergeneric hybridization.

3.3.1. Intraspecific Hybridization

When hybridization takes place in the same species of different sources it is called intraspecific hybridization. The possibilities of F_1 crossbreeding in intraspecific hybridization are for performance and genetic uniformity. Further possibilities for intraspecific hybridization are i) the use of different subspecies and ii) the crossing of fish from distant populations, which have not, however, achieved the taxonomic status of subspecies (Purdon, 1983).

The crossing of different subspecies is not well documented. One major example was studied by (Moav, 1967) who assessed conservational impact of hybridization, not its purposeful deployment. The consequences of hybridization were potentially harmful. The opposite conclusion on racial crosses was reached for the hybrid common carp, *Cyprinus carpio*, produced by crossing European and Chinese strains (Moav *et al.*, 1963).

3.3.1.1. Intraspecific hybridization in common carp *Cyprinus carpio*:

Three European 'domesticated' strains and one Chinese strain were compared with all possible hybrids. No data on survival were recorded but on growth rate, the author found significant differences between all four strains and clear evidence of heterosis. A great deal of the variance for growth was attributed to environmental factors of pond and farm and non-linear social interactions were taken into account in demonstrating their presence

of strong heterosis. At face value, and bearing in mind the derived status of the weight-gain estimates, some of the hybrid comparisons looked more like intermediate patterns of inheritance, and only in one cross was heterosis marked. Marked heterosis is also claimed for intervarietal crosses of Chinese common carp with hybrids showing 20% better growth than the better parent, and sustained improvement was also seen in F_2 and backcrosses (Zhang, 1990). No statement was made on the degree of inbreeding of these stocks, but the inbreeding history of the European stocks was known and is commensurate with a low level of heterosis.

That some hybrid vigour occurs more often for interracial crosses than for interspecific hybrids seems reasonably well established. For domesticated strains where there is some evidence of inbreeding there may also be some evidence of heterosis, but in neither case does it appear as if strong heterotic forces are at work.

Besides this, various scientists carried out intraspecific hybridization in different countries in different time.

3.3.1.2. Intraspecific hybridization in rohu (*L. rohita*) in India:

In India intraspecific hybridization was carried out among the members of stocks from different rivers, which were termed as complete diallele crosses. One with the stocks of river Ganga, Local (farm) and River Yamuna (Diallel-1) and the other with the stocks of River Brahmaputra, Local and River Sutlej (Diallele-2). The milt from each sire of each stock (5 sires/stock) was used to fertilize an equal amount of eggs from the females of the same or a different stock (8-10 females/stock).

The results of the two diallele-crosses indicated low average heterosis effects for both harvest body weight and survival. For diallele-2, significant negative average heterosis for body weight was observed in both mono and polyculture production systems. The results thus suggest that systematic crossing of rohu stocks may not yield any progeny with positive heterosis. No. of crosses is given in Tables 2 and 3.

Table 2: No. of crosses (Diallele 1) (Chaudhuri, 1971)

Female		Male	Comments
1. Ganga	X	Ganga (GG)	Normal/control cross
2. Ganga	X	Yamuna (GY)	No heterosis exhibited
3. Ganga	X	Local (GL)	No heterosis exhibited
4. Yamuna	X	Ganga (YG)	No heterosis exhibited
5. Yamuna	X	Yamuna (YY)	Normal/control cross
6. Yamuna	X	Local (YL)	No heterosis exhibited
7. Local	X	Ganga (LG)	No heterosis exhibited
8. Local	X	Yamuna (LY)	No heterosis exhibited
9. Local	X	Local (LL)	Normal/control cross

Table 3: No. of crosses (Diallele 2) (Chaudhuri, 1971)

Female		Male	Comments
1. Sutlej	X	Sutlej (SS)	Normal/control cross
2. Sutlej	X	Brahmaputra (SB)	No heterosis exhibited
3. Sutlej	X	Local (SL)	No heterosis exhibited
4. Brahmaputra	X	Sutlej (BS)	No heterosis exhibited

5. Brahmaputra	X	Brahmaputra (BB)	Normal/control cross
6. Brahmaputra	X	Local (BL)	No heterosis exhibited
7. Local	X	Sutlej (LS)	No heterosis exhibited
8. Local	X	Brahmaputra (LB)	No heterosis exhibited
9. Local	X	Local (LL)	Normal/control cross

3.3.1.3. Intraspecific hybridization of cultured carp with wild carp in USSR:

3.3.1.3.1. Scattered carp × wild carp:

Explicit heterosis was advantageous, both in growth and survival. Moreover, high resistance of hybrids to infectious dropsy is undoubted. By the second summer, growth heterosis disappears (Kirpichnikov and Balkashina, 1935).

3.3.1.3.2. Galician carp x Taparavan carp:

Hybrids exceed the parental carp in weight by 37 percent, and under unfavourable rearing conditions the difference increases up to 110 percent. Mortality of hybrid fingerlings is 1.4 percent, whereas that of carp constitutes 24.8 percent. A large number of inherited malformations occur in Taparavan carp causing retardation in its growth and a high percentage of waste, especially in the wintering season (Kirpichnikov and Balkashina, 1935).

3.3.1.3.3. Cultured carp x Amur wild carp:

Heterosis in weight growth of hybrid young is 5–10 percent higher than that of initial forms and in viability heterosis expresses itself most clearly under unfavourable conditions of rearing (difference is in the range of 30–50 percent) and at early stages of development (hybrid larvae survive better than parents by 10–20 percent). Later, these differences become less and heterosis appears to fade away, although during the first or second years the hybrids retain larger sizes than wild carp or cultured carp (Kirpichnikov, 1958).

3.3.1.3.4. Interbred crosses of carp:

In the crossing of Ropsha carp with Ukrainian carp and in joint rearing of two years old it was found that the interbred hybrid exceeds the Ukrainian carp in growth by 25 percent or more, while Ukrainian and Ropsha carp jointly reared in one pond did not differ from each other in their weight (Kuzema, 1965).

3.3.1.4. Intraspecific hybridization in Indian Major Carp in Bangladesh:

In Bangladesh intraspecific hybridization has been carried out in different time by various scientists. Islam and Shah (2007) conduct a comparative hybridization programme between hatchery-produced seed and seed that are produced by crossing hatchery and natural strain. He considered three Indian major carp namely *Labeo rohita*, *Catla catla* and *Cirrhinus mrigala*. In case of hatchery he did not make reciprocal crosses but he made reciprocal crosses in hatchery and natural strain and get the following result.

3.3.1.4.1. Cross in *Labeo rohita* (Rohu):

Cross in *Labeo rohita* (Rohu) is given in Table 4.

Table 4: Cross in *Labeo rohita* (Rohu) (Chaudhuri, 1971)

FEMALE	MALE	HYBRID	COMMENTS
Hatchery x Hatchery		Hatchery-Hatchery	Control Cross
Hatchery x Jamuna		Hatchery-Jamuna	Better growth than control
Jamuna x Hatchery		Jamuna -Hatchery	Better growth than control
Hatchery x Padma		Hatchery-Padma	Better growth than control
Padma x Hatchery		Padma-Hatchery	Better growth than control

3.3.1.4.2. Cross in *Catla catla* (Catla):

Cross in *Catla catla* (Catla) is given in Table 5.

Table 5: Cross in *Catla catla* (Catla) (Chaudhuri, 1971)

FEMALE	MALE	HYBRID	COMMENTS
Hatchery x Hatchery		Hatchery-Hatchery	Control Cross
Hatchery x Jamuna		Hatchery-Jamuna	Better growth than control
Jamuna x Hatchery		Jamuna -Hatchery	Better growth than control
Hatchery x Padma		Hatchery-Padma	Better growth than control
Padma x Hatchery		Padma-Hatchery	Better growth than control

3.3.1.4.3. Cross in *Cirrhinus cirrhosus* (Mrigal):

Table 6 describes about cross in *Cirrhinus cirrhosus* (Mrigal):

Table 6: Cross in *Cirrhinus cirrhosus* (Mrigal) (Chaudhuri, 1971)

FEMALE	MALE	HYBRID	COMMENTS
Hatchery x Hatchery		Hatchery-Hatchery	Control Cross
Hatchery x Jamuna		Hatchery-Jamuna	Lower growth than control
Jamuna x Hatchery		Jamuna -Hatchery	Lower growth than control
Hatchery x Padma		Hatchery-Padma	Better growth than control
Padma x Hatchery		Padma-Hatchery	Better growth than control

It was found that all hatchery-natural hybrids showed better growth than the hatchery-hatchery hybrid except hatchery-Jamuna (*Cirrhinus cirrhosus*) hybrid. He explicated the reason of the lowered growth of the hatchery produced hybrid is due to environmental than genetic.

3.3.2. Interspecific Hybridization

When hybridization takes place in the different species of same genus then it is called interspecific hybridization.

3.3.2.1. Interspecific hybridization between Indian major carps

Interspecific hybridization between Indian major carps is given in Table 7.

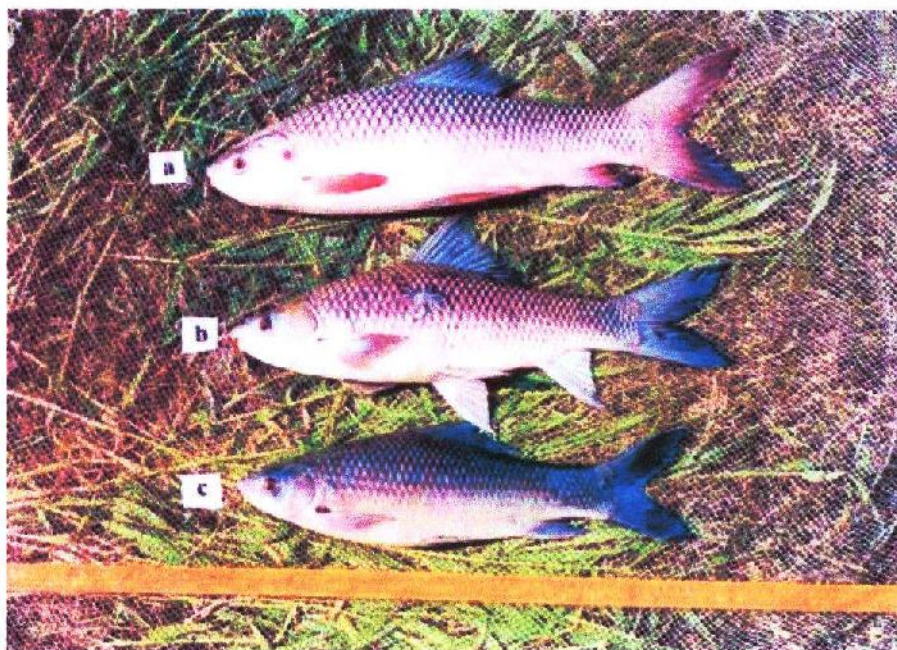
Table 7: List of interspecific hybrids between Indian major carps (Chaudhuri, 1971)

FEMALE	MALE	HYBRID	COMMENTS
1 <i>L.rohita</i> × <i>L.calbasu</i>		(rohu-kalbasu)	Hybrid grows faster than Kalbasu and fertile.
2. <i>L.calbasu</i> × <i>L. rohita</i>		(kalbasu-rohu)	Hybrid grows faster than Kalbasu and fertile.
3. <i>L.rohita</i> × <i>L. bata</i>		(rohu-bata)	Hybrids exhibited poor hatching and slow growth rate.
4. <i>L.calbasu</i> × <i>L. bata</i>		(kalbasu-bata)	Hybrids exhibited poor hatching and slow growth rates.
5. <i>L. gonius</i> × <i>L.calbasu</i>		(gonius-kalbasu)	Hybrids exhibited poor hatching and slow growth rates.
6. <i>L. fimbriatus</i> × <i>L.rohita</i>		(fimbriatus-rohu)	Hybrids grow faster than fimbriatus and have better feeding efficiency.

Characteristics of mentioned above six interspecific hybrids produced and evaluated are described.

3.3.2.1.1. *Labeo rohita* (Female) x *Labeo calbasu* (Male) (rohu-kalbasu) hybrids:

The percentage of fertilization was very high reaching about 94% and development of eggs was normal. The offspring of the hybrid cross was highly viable and its growth rate was superior to its slow growing parent viz. *L. calbasu* (Chaudhuri, 1971). Hybrid of the cross was found to be fertile and attained maturity within two years. (Fig 1).



(Source: FAO Fisheries Technical report)

Fig: 1. Interspecific hybrids cross between female *L. rohita* and male *L. calbasu*

a. *L. rohita* b. Hybrid c. *L. calbasu*

3.3.2.1.2. *Labeo calbasu* (Female) x *Labeo rohita* (Male) (kalbasu-rohu) hybrids:

Percentage of fertilization was very high reaching about 94% and development of eggs was normal. The offspring of the hybrid cross was highly viable and its growth rate was superior to its slow growing parent viz. *L. calbasu*. Hybrid of the crosses was found to be fertile and attained maturity within two years (Chaudhury, 1971). (Fig 2)



(Source: FAO Fisheries Technical report)

Fig 2. Reciprocal interspecific hybrid-cross between female *L. calbasu* and male *L. rohita*

a. L. calbasu b. Hybrid c. L. rohita

3.3.2.1.3. *L. rohita* (Female) x *L. bata* (Male) (rohu-bata), *L. calbasu* (Female) x *L. bata* (Male) (kalbasu-bata) and *L. gonius* (Female)x *L. calbasu* (Male) (gonius-kalbasu) hybrids:

As in the case of kalbasu-rohu and the reciprocal hybrids, the percentage of fertilization and embryonic development of these hybrid offspring's were normal, although the percentage of hatching was reported to be poor. Rohu-bata and kalbasu-bata hybrids did not show much promise (Chondar, S.L. 1977). The latter hybrid exhibited good initial growth.

3.3.2.1.4. *L. fimbriatus* (Female) x *L. rohita* (Male) (fimbriatus-rohu) hybrid:

The growth of the hybrid was evaluated in comparison to the parent species. In an 182 day rearing experiment the hybrid was reported to attain 247.8g as compared to 324.5g in

rohu and 161.7g in fimbriatus. The growth in the hybrid was 34.75% higher than that of fimbriatus and 23.55 less than rohu. The hybrid also showed the highest survival, being 90% compared to rohu with 86.67% and fimbriatus, 76.67%. In terms of percentage weight gain, specific growth rate and feed utilization, the hybrid performed better than both the parental species. Almost all the hybrids, either interspecific or intergeneric, produced among Indian major carps in general exhibited intermediate traits to their parental species (Basavaraju *et al.*, 1990).

3.3.2.2. Interspecific hybridization between Common carps

Interspecific hybridization between Common carps was found between their different scale patterns. So before discussing hybridization, one should know about their scale pattern. Scientific works by Kirpichnikov and Balkashina (1935), Golovinskaya (1940) and Kirpichnikov (1937) demonstrate two pairs of autosomal unlinked genes, which determine the type of scaliness in carps. The following carp genotypes are possible: (Table 8).

Table 8: Possible common carp genotypes (Kirpichnikov, 1937)

SSnn, Ssnn	-	scaled
ssnn	-	scattered
SSNn, SsNn	-	linear
ssNn	-	leather



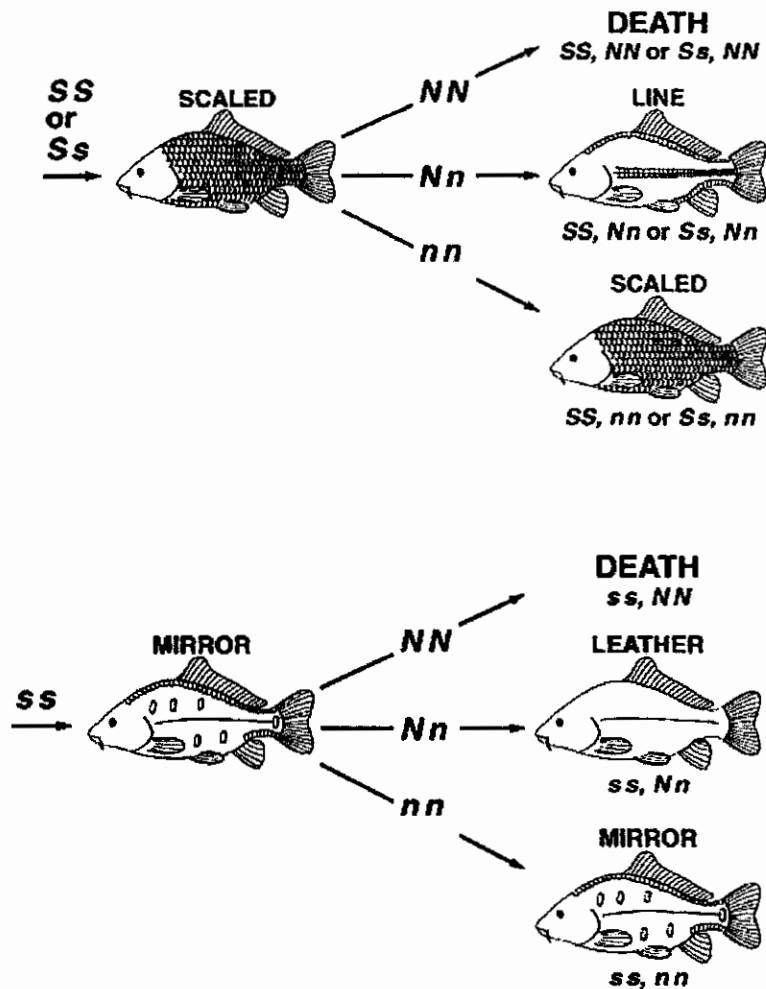


Fig 3. Inheritance of scale pattern in common carp.

Scale pattern is determined by the epistatic interaction between the S and N genes. The S gene determines whether the fish has the scaled phenotype (SS and Ss genotypes) or the mirror phenotype (ss genotype). The N gene modifies those phenotypes. The NN genotype kills the fish (SS, NN, Ss, NN, and ss, NN genotypes); the Nn genotype changes the scaled phenotype into the line phenotype (SS, Nn and Ss, Nn genotypes) and changes the mirror phenotype into the leather phenotype (ss, Nn). The nn genotype does not alter the phenotypes produced by the S gene, so scaled fish have the SS, nn or Ss, nn genotypes, while mirror fish have the ss, nn genotype.

Carp with genotypes SSNN, SsNN and ssNN are not viable. N gene is lethal in the homozygous state and embryos die in the hatching stage. This gene has a reducing effect on many organs of heterozygous carp (Golovinskaya, 1940; Kirpichnikov, 1945;).

Following Table gives the results of all possible crossings of carp having different types of scale patterns. Segregation corresponds to the expected pattern; but the number of linear and leather carps is low due to their lower viability. At lower mortality rates, the correspondence of the actual and theoretical frequencies may be closer. Scale cover inheritance in common carp is given in Table 9.

Table 9: Scale cover inheritance in common carp (Kirpichnikov, 1937)

Parents (Irrespective of sex)	Number of offsprings (in percent)			
	<u>Sc</u>	<u>St</u>	<u>Lin</u>	<u>Leath</u>
1. <u>Sc</u> × <u>Sc</u>	100	-	-	-
	75	25	-	-
2. <u>Sc</u> × <u>St</u>	100	-	-	-
	50	50		
3. <u>Sc</u> × <u>Lin</u>	50	-	50	
	37.5	12.5	37.5	12.5
4. <u>Sc</u> × <u>Leath</u>	50	-	50	-
	25	25	25	25
5. <u>St</u> × <u>St</u>	-	100	-	-
6. <u>St</u> × <u>Lin</u>	50	-	50	-

	25	25	25	25
7. <u>St</u> × <u>Leath</u>	-	50	-	50
8. <u>Lin</u> × <u>Lin</u>	33.3	-	66.7	-
	25	8.3	50	16.7
9. <u>Lin</u> × <u>Leath</u>	33.3	-	66.7	-
	16.7	16.7	33.3	33.3
10. <u>Leath</u> × <u>Leath</u>	-	33.3	-	66.7

Sc: scaled, St: scattered, Lin: linear, Leath: leather

3.3.3. Intergeneric Hybridization

When hybridization takes place in the different species of different genus then it is called intergeneric hybridization.

3.3.3.1. Intergeneric hybrids between Indian major carps

List of intergeneric hybrids between Indian major carps is given in Table 10.

Table 10: List of intergeneric hybrids between Indian major carps (Chaudhuri, 1971)

FEMALE	MALE	HYBRID	COMMENTS
1. <i>C. catla</i> × <i>L. rohita</i>		(catla-rohu)	Growth rate of hybrids variable, grow better than both the parents (Varghese and Sukumaran, 1971), grow slower

		than both the parents (Konda Reddy & Verghese, 1983), fertile hybrids.
2. <i>L.rohita</i> × <i>C. catla</i>	(rohu-catla)	Hybrids grow faster than rohu. The meat yield in hybrids is higher than in parents. The hybrids are fertile.
3. <i>C. catla</i> × <i>C. mrigala</i>	(catla-mrigal)	Hybrids grow slower than the parents and are fertile.
4. <i>C. mrigala</i> × <i>C. catla</i>	(mrigal-catla)	Hybrids grow better than either parents and are fertile.
5. <i>L.rohita</i> × <i>C. mrigala</i>	(rohu-mrigal)	Growth rate of hybrids variable, grow better than the parent species (Ibrahim, 1977), grow slower than both the parents (Basavaraju and Varghese, 1980). The hybrids are fertile.
6. <i>C. mrigala</i> × <i>L.rohita</i>	(mrigal-rohu)	Hybrids grow slower than both the parents and are fertile.
7. <i>C. catla</i> × <i>L.calbasu</i>	(catla-kalbasu)	Hybrids grow faster than kalbasu and they have broader feeding spectrum & adaptability.
8. <i>L. calbasu</i> × <i>C. catla</i>	(kalbasu-catla)	Hybrids exhibited low viability, need further study with regard to survival & performance.
9. <i>L.calbasu</i> × <i>C.</i>	(kalbasu-	Fertilization in the hybrid cross was

		than both the parents (Konda Reddy & Verghese, 1983), fertile hybrids.
2. <i>L.rohita</i> × <i>C. catla</i>	(rohu-catla)	Hybrids grow faster than rohu. The meat yield in hybrids is higher than in parents. The hybrids are fertile.
3. <i>C. catla</i> × <i>C. mrigala</i>	(catla-mrigal)	Hybrids grow slower than the parents and are fertile.
4. <i>C. mrigala</i> × <i>C. catla</i>	(mrigal-catla)	Hybrids grow better than either parents and are fertile.
5. <i>L.rohita</i> × <i>C. mrigala</i>	(rohu-mrigal)	Growth rate of hybrids variable, grow better than the parent species (Ibrahim, 1977), grow slower than both the parents (Basavaraju and Varghese, 1980). The hybrids are fertile.
6. <i>C. mrigala</i> × <i>L.rohita</i>	(mrigal-rohu)	Hybrids grow slower than both the parents and are fertile.
7. <i>C. catla</i> × <i>L.calbasu</i>	(catla-kalbasu)	Hybrids grow faster than kalbasu and they have broader feeding spectrum & adaptability.
8. <i>L. calbasu</i> × <i>C. catla</i>	(kalbasu-catla)	Hybrids exhibited low viability, need further study with regard to survival & performance.
9. <i>L.calbasu</i> × <i>C.</i>	(kalbasu-	Fertilization in the hybrid cross was

<i>mrigala</i>	mrigal)	normal (80–90%) with 60% hatching rate. The hybrids are fertile.
10. <i>L.rohita</i> × <i>C. reba</i>	(rohu-reba)	Hybrids exhibit low viability.
11. <i>L.calbasu</i> × <i>C. reba</i>	(kalbasu-reba)	Hybrids exhibit low viability.
12. <i>C. catla</i> × <i>L. fimbriatus</i>	(catla-fimbriatus)	Hybrids grow much faster than <i>L. fimbriatus</i> . The meat yield is higher than the parents.
13. <i>L. fimbriatus</i> × <i>C. catla</i>	(fimbriatus-catla)	Hybrids grow much faster than <i>L. fimbriatus</i> . The meat yield is higher than the parents.

Of these intergeneric hybrids produced only four hybrids, *L. rohita*-*C. catla*, *Cirrhinus mrigala*-*C. catla*, *L. rohita*-*Cirrhinus mrigala*, *L. fimbriatus*-*C. catla* and the reciprocal hybrids have been found to possess useful traits in terms of growth (Ibrahim, 1977; Basavaraju and Varghese, 1981).

The following are the characteristics of all these hybrids.

3.3.3.1.1. *L. rohita* (Male) × *C. catla* (Female) (rohu-catla) hybrid:

Phenotypically the hybrid exhibits intermediate traits to that of the parents, but tending more towards the maternal parent (*L. rohita*) with regard to body proportions and fin ray counts. Coloration of the body of the hybrid was near to catla while the shape of the mouth was like rohu. However, its position with infringed lips was terminal and devoid of barbels. The hybrid possessing a smaller head than that of catla and wider body than rohu shows improved traits over the parents. The flesh content of the rohu-catla hybrid, 54–

58%, has been also reported to be the highest when compared to rohu with 48–52% and catla with 45% (Bhowmick *et al.*, 1981b and Jana, 1993). (Fig 4).



(Source: FAO Fisheries Technical report)

Fig 4. Reciprocal intergeneric hybrid-cross between female *C.catla* and male *L.*

rohita

a. C. catla b. Hybrid c. L. rohita

3.3.3.1.2. *C. catla* (Male) x *L. rohita* (Female) (catla-rohu) hybrid:

Konda Reddy and Varghese (1983) produced this catla-rohu intergeneric hybrid and studied the embryonic and larval developments and compared with the parental species. They reported that the developmental stages of the hybrid were quite normal and no abnormalities were noticed and were similar to the parental species.

Hybrid grows better than catla under monoculture as well as when grown with catla Alikunhi *et al.* (1971). Hybrid grow better than both the parents (Varghese and Sukumaran, 1971). According to Chaudhuri (1971), the progeny inherits the small head

of *L. rohita* and the large body of *C. catla*, and thus gains an advantage over parental forms in the weight of the edible part. The F_2 is characterized by good growth. (Fig 5).



(Source: FAO Fisheries Technical report)

Fig 5. Intergeneric hybrid-cross between female *L. rohita* and male *C. catla*

a. *L. rohita* b. Hybrid c. *C. catla*

3.3.3.1.3. *C. catla* (Female) x *Cirrhinus mrigala* (Male) (catla-mrigal) hybrid:

Ibrahim (1977) made a thorough investigation of the hybrids produced between *C. catla* female and *Cirrhinus mrigala* male and the reciprocal hybrids and also the hybrid between *L. rohita* female and *C. mrigala* male. From the viewpoint of the morphometric characters, the hybrid differed from the parental forms with regard to fin ray counts, dorsal, pectoral and pelvic fin rays, and tended more towards the maternal parent, the catla.

3.3.3.1.4. *Cirrhinus mrigala* (Female) x *C. catla* (Male) (mrigal-catla) hybrid:

The hybrid was found to be intermediate to the parents. The significant morphometric characters are the depth of body and size of head of the hybrid which are positive gains (Ibrahim, 1977).

3.3.3.1.5. *L. rohita* (Male) x *Cirrhinus mrigala* (Female) (rohu-mrigal) hybrid:

Hybrid cross had a very high percentage of fertilization (97.9%). Basavaraju and Varghese (1981) studied the growth rates of the *L. rohita* (female) x *Cirrhinus mrigala* (male) and the reciprocal hybrids and compared them with that of the parental species, which were also reared along with the hybrids. This study has shown that the parental species, *L. rohita* and *Cirrhinus mrigala* grew faster than both the hybrids. Again, between the two hybrids the hybrid between *Cirrhinus mrigala* female x *L. rohita* male grew faster than the reciprocal *L. rohita* female x *C. mrigal* male hybrid.

3.3.3.1.6. *Cirrhinus mrigala* (Male) x *L. rohita* (Female) (mrigal-rohu) hybrid:

In the mrigal-rohu hybrid the eggs were intermediate in size. The development of the mrigal-rohu hybrid was normal and similar to that of parent species. With regard to the morphological features, the hybrid exhibited intermediate traits between the parents (Basavaraju and Varghese, 1981).

3.3.3.1.7. *C. catla* (Female) x *L. calbasu* (Male) (catla-kalbasu) hybrid:

Morphologically the hybrid has a greater resemblance with kalbasu in general appearance, indicating paternal dominance. The hybrid had a smaller head than catla and body girth greater than kalbasu. The quantity of flesh in the hybrid was also greater than that of both parents. The hybrid possessed a terminal mouth with thick lips. The feeding habits of the hybrid seem to be broadly varied as evidence by the gut contents, comprising crustaceans, chironomid larvae, rotifers, diatoms, other algal forms, sand and mud. The hybrid also relishes artificial feed which was also observed in the gut in various stages of digestion. Thus the hybrid has a broader feeding spectrum and higher degree of adaptability for different food items from various niches of the pond (Bhowmick *et al.*, 1981a).

3.3.3.1.8. *L. calbasu* (Female) x *C. catla* (Male) (kalbasu-catla) hybrid:

This cross between female *L. calbasu* and male *C. catla* did not yield any appreciable percentage of viable progeny. The development of eggs after insemination was abnormal and only about 20% of them hatched out, of which only a small percentage survived (Bhowmick *et al.*, 1981a).

3.3.3.1.9. *L. calbasu* (Female) x *C. mrigala* (Male) (kalbasu-mrigal) hybrid:

This hybrid produced from crosses between female *L. calbasu* and male *C. mrigala* showed normal fertilization with a 60% hatching rate. The hybrid had a slightly fringed lower lip and two pairs of prominent black barbels resembling that of maternal parent. Body color of the hybrid was intermediate between the parent species. No further details

are available regarding the growth performance. However, the hybrids have been reported to attain maturity in 2-3 years (Bhowmick *et al.*, 1981a).

3.3.3.1.10. *L. rohita* (Female) x *C. reba* (Male) (rohu-reba) and *L. calbasu* (Female) x *C. reba* (Male) (kalbasu-reba) hybrids:

These intergeneric hybrid crosses between female *L. rohita* and male *C. reba* did not result in any viable hybrids. Only about 20% of the hybrid zygotes hatched out but all the hatchlings died on the third day after hatching. Alikunhi *et al.* (1971) also attempted to upgrade *C. reba* by crossing it with the males of rohu, mrigal and grass carp. The hatchlings in all the three crosses were observed to be longer than those of *C. reba*. However, all the hatchling died within two days.

3.3.3.1.11. *L. fimbriatus* (Female) x *C. catla* (Male) (fimbriatus-catla) and *C. catla* (Female) x *L. fimbriatus* ((Male) (catla-fimbriatus) hybrids:

Basavaraju *et al.* (1994) studied the morphometric and meristic characters of the hybrid between *L. fimbriatus* female and *C. catla* male in comparison with the parental species. These authors stated that it was difficult to distinguish these reciprocal hybrids.

The fimbriatus-catla hybrid also possessed intermediate characters to parental species in body profile, coloration of fins and structure of lips. Body was deep with a smaller head than in the paternal parent catla. The Mouth was subterminal with a moderately fringed lower lip.

With regard to the morphometric characters, the hybrid resembled catla (male parent) in total length/standard length, length of head/eye diameter and length of head/height of head. Its resemblance with the female parent (fimbriatus) was only in respect of head length/maximum head width. The intermediate characters were total length/fork length, total length/pro-dorsal length and total length/least height of caudal peduncle (Basavaraju *et al.*, 1994).

3.3.3.2. Intergeneric hybrids between Indian major carps and Common carp



The hybrids between Indian major carps and common carp (*Cyprinus carpio* var. *communis*), involving the crosses between common carp male $\times$ rohu female, common carp female $\times$ males of rohu, catla and mrigal in each cross, respectively have on the whole exhibited normal fertilization and moderate viability, though in certain cases, the crosses involving females of Indian carps with males of common carp, low viability has been exhibited in the hybrids. Details of these intergeneric hybrid crosses are shown in Table 11.

Table 11: List of Intergeneric hybrids between Indian major carps and Common carp (Chaudhuri, 1971)

FEMALE	MALE	HYBRID	COMMENTS
1. <i>L.rohita</i>	$\times$ <i>C. carpio</i>	(rohu-common carp)	Hybrids exhibited poor survival and are sterile.
2. <i>C. mrigala</i>	$\times$ <i>C. carpio</i>	(mrigal-common carp)	Poor survival. The hybrid tends to resemble <i>C. carpio</i> and is

		sterile.
3. <i>C. carpio</i> × <i>L. rohita</i>	(common carp-rohu)	Higher survival rate than the reciprocal-cross and dominated by mostly <i>C. carpio</i> traits. The hybrids are sterile (aneuploid), grow better under monoculture system.
4. <i>C. carpio</i> × <i>C. catla</i>	(common carp-catla)	Higher survival rate than the reciprocal-cross and dominated by mostly <i>C. carpio</i> traits. The hybrids are sterile (aneuploid), grow better under monoculture system.
5. <i>C. carpio</i> × <i>C. mrigala</i>	(common carp-mrigal)	Hybrids are inferior to both the parents in growth and are sterile.

Characteristics of hybrids produced between Indian major carps and common carp (*Cyprinus carpio* var. *communis*):

The characteristics of these intergeneric hybrids also more or less exhibited intermediate traits, though some traits were characteristic of the maternal parent and in others of the paternal parent.

3.3.3.2.1. *L. rohita* (female) x *C. carpio* (male) (rohu-common carp) hybrid:

Though the percentage of fertilization appeared to be good, the development in many of the eggs ceased during the incubation period. The bulk of the embryos died during and after hatching and only a few hatchlings could grow up to the adult stage, which did not show any signs of maturity.

Morphologically, the hybrid appeared to be intermediate between the parents but statistical analysis of various parameters showed it to be closer to the paternal parent (common carp). (John and Reddy, 1987).

3.3.3.2.2. *C. carpio* (female) x *L. rohita* (male) (common carp-rohu) hybrid:

Khan *et al.*, (1990) made a detailed study of this hybrid cross between common carp female and *L.rohita* male. The fertilization rate was as good as in pure common carp crosses. Hatching process was completed within 46.30 hrs at water temperature 27–29.5° C.

The dorsally convex and elongated body of the hybrid was broader than that of rohu. In other morphological features the hybrid had a terminal mouth, which was also protractile as in common carp. The lips were not fringed but one pair of maxillary and another pair of rostral barbels were present. Regarding the fins, the dorsal fin though long, but was shorter than in common carp. Serrations of the spiny dorsal and anal fin rays, which are very conspicuous in common carp, were very feeble in the hybrid. The hybrid resembled the common carp in prepectoral distance, the lateral line position, and color of the body.

84.3g and 68.5%, 237g and 70% and 216.7g and 88% respectively. Thus the hybrid has shown slower growth and lower survival than both the parents, when grown together.

Regarding food habits, these hybrids are bottom feeders as the maternal parent and their food items consisted of semidigested crustacean appendages, bottom detritus and sand particles. Diatoms like *Amphora*, *Navicula* and filamentous alga were also observed in the food. The dress value of the hybrid had a higher percentage of flesh (58%) than that of common carp (47%), but less than in rohu (60.3%).

Regarding fertility, the hybrid did not exhibit any signs of maturity after two to four years of age. However, rudiments of testes were observed in some individuals (Khan *et al.*, 1990).

3.3.3.2.3. *C. mrigala* (Female) x *C. carpio* (Male) (mrigal-common carp) hybrid:

These hybrids have a high rate of fertilization. However, about 40% mortality was recorded during embryonic and larval development. Only a few hybrids could be reared to adult size, i.e. to 242mm/120g after 14 months rearing in nursery ponds.

The hybrid had a greater body growth than the maternal parent (mrigal) and a smaller head than in common carp. Though the outline of the mouth was similar to that of mrigal, it was protractile as in the paternal parent (common carp). The hybrid resembled common carp in having an elongated dorsal fin, moderately forked caudal fin and in scale and color pattern (Kowtal and Gupta, 1985).

3.3.3.2.4. *C. carpio* (Female) x *C. mrigala* (Male) (common carp-mrigal) hybrid:

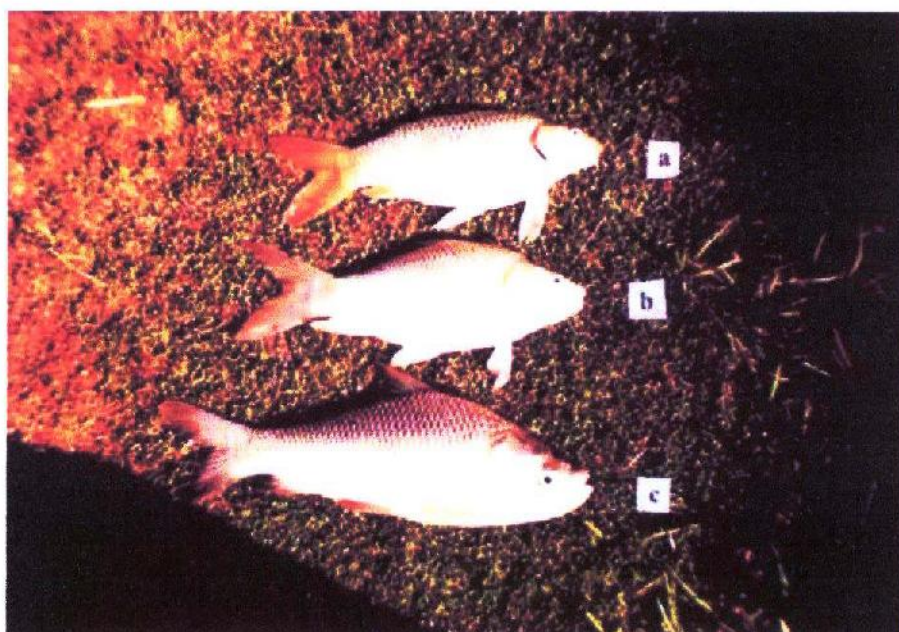
As in the case of common carp-rohu hybrid, in this cross the rate of fertilization was similar to pure common carp crosses. In embryonic and larval development the hybrid followed more or less the pattern of maternal parent (common carp). Hatching commenced from 23 hours after fertilization and was completed by 44-49 hours at 27-29°C.

Like the common carp-catla hybrid this hybrid possessed a dorsally convex body with a slight hump as in common carp, but without the characteristic big belly of mrigal. However, the body was more elongated and broader than mrigal. The terminal mouth of the hybrid was not protractile as in the case of common carp. Barbels, one pair of maxillary and the other mandibular were present. All this, the shape of snout (blunt) and the eye located in the anterior portion of the head, made the hybrid similar to the common carp. The traits resembling mrigal were the elongated body without big belly and non protractile mouth and the pattern of lateral line.

The variable color of the hybrid, back greenish, sides golden yellow with a whitish ventral surface and grayish dorsal and caudal is an intermediate in appearance, at the same time the hybrid exhibits traits, which tends more towards the maternal parent, the common carp. Regarding growth, the common carp-mrigal hybrid attained 48.2 g under monoculture system, but it grew to only 10.2 g in polyculture during the span of 110 days rearing. However, the parent species common carp and mrigal registered a weight of 107.4 g and 110.8 g respectively in the same polyculture system under the same rearing conditions. Thus the growth performance of this hybrid was slightly better than only mrigal (paternal parent), when the former was reared under monoculture (Khan *et al*, 1990).

3.3.3.2.5. *C. carpio* (Female) x *C. catla* (Male) (common carp-catla) hybrid:

The cross of common carp female with male of *C. catla* showed a relatively high percentage of fertilization, ranging from 65–80%, but in this case also about 35–45% mortality occurred during embryonic development, as in the case of the mrigal-common carp hybrid. Most of the hatchlings were deformed with a curve in the caudal region and died 72 hrs after hatching. The hybrid possessed a dorsally convex and more elongated body than common carp. A slight hump as in the case of common carp was also present. As in the case of the common carp rohu hybrid, the characteristic belly of the common carp was lacking in this hybrid too. The mouth of the hybrid was terminal and shorter than that of common carp (Khan *et al.*, 1990). (Fig 7).



(Source: FAO Fisheries Technical report)

Fig 7. Intergeneric hybrid-cross between female *C. carpio* and male *C. catla*

a. *C. carpio* b. Hybrid (sterile) c. *C. catla*

3.3.3.3. Hybridization of Common carp with crucian carp

3.3.3.3.1. *Cyprinus carpio* × *Carassius carassius*

Carp × crucian carp hybrids inherited the resistance of *C. carassius* and the high growth rate of common carp. The limited fecundity of hybrids made it possible for a long time to utilize only the first generation for the purpose of commercial fish farming (Kuzema, 1965).

3.3.3.4. Intergeneric hybridization between Chinese carp

Intergeneric hybridization between Chinese carp is given in Table 12.

Table 12: List of intergeneric hybridization between Chinese carps (Chaudhuri, 1971)

SPECIES	HYBRID	COMMENTS
1. <i>H. molitrix</i> x <i>Arcticthyes nobilis</i>	(silver carp-bighead carp)	Hybrids show a good growth rate (Voropaev, 1968). Hybrids are not viable (Alikunhi, <i>et.al.</i> , 1963).
2. <i>C. idella</i> x <i>H. molitrix</i>	(grass carp-silver carp)	Hybrids are not viable to maturity.
3. <i>C. idella</i> x <i>Arcticthyes nobilis</i>	(grass carp- bighead carp)	Hybrids are not viable.

3.3.3.4.1. *H. molitrix* (Female) x *Arcticthyes nobilis* (Male) (silver carp-bighead carp) and *H. molitrix* (Male) x *Arcticthyes nobilis* (Female) (bighead carp-silver carp) hybrid:

These intergeneric hybrids show a good growth rate, especially under the conditions of limited food supply in ponds. As in coregonid hybrids, this feature seems to be attributed to the intermediate structure of pharyngeal apparatus (Voropaev, 1968).

In a few cases the eggs got fertilized but did not hatch out, while in others the hatchlings survived up to a maximum of one week (Alikunhi *et al.*, 1963).

3.3.3.4.2. *C. idella* (Female) x *H. molitrix* (Male) (grass carp-silver carp) and *C. idella* (Male) x *H. molitrix* (Female) (silver carp-grass carp) hybrid:

True (diploid) hybrids of Chinese grass carp and silver carp were not found viable to maturity, though these two species possess equal number of diploid chromosomes ($2n=48$ in each case). (Alikunhi *et al.*, 1963).

3.3.3.4.3. *C. idella* (Female) x *Arcticthytes nobilis* ((Male) (grass carp-bighead carp) and *C. idella* (Male)x *Arcticthytes nobilis* ((Female) (bighead carp-grass carp) hybrid:

In a few cases the eggs got fertilized but did not hatch out, while in others the hatchlings survived up to a maximum of one week (Alikunhi, *et al*, 1963).

3.3.3.5. Intergeneric hybridization between Indian and Chinese carp

Intergeneric hybridization between Indian and Chinese carp is given in Table 13.

Table 13: List of intergeneric hybridization between Indian and Chinese carps

(Chaudhuri, 1971)

FEMALE	MALE	HYBRID	COMMENTS
1. <i>L. rohita</i> x <i>H. molitrix</i>		(rohu-silver carp)	Hybrids are not viable beyond larval stage.
2. <i>C. catla</i> x <i>H. molitrix</i>		(catla-silver carp)	Few hybrids survived only over two months.
3. <i>H. molitrix</i> x <i>C. catla</i>		(silver carp-catla)	Few hybrids survived only over two months.
4. <i>L. rohita</i> x <i>C. idella</i>		(rohu-grass carp)	Hybrids are not viable beyond larval stage.
5. <i>C. mrigala</i> x <i>C. idella</i>		(mrigal-grass carp)	Hybrids are not viable beyond larval stage.
6. <i>C. idella</i> x <i>C. catla</i>		(grass carp-catla)	Hybrids are not viable beyond larval stage.
7. <i>C. idella</i> x <i>L. rohita</i>		(grass carp-rohu)	Hybrids are not viable beyond larval stage.
8. <i>A. nobilis</i> x <i>C. catla</i>		(bigheadcarp-catla)	Hybrids are not viable beyond larval stage.
9. <i>A. nobilis</i> x <i>L. rohita</i>		(bighead carp-rohu)	Hybrids are not viable beyond larval stage.

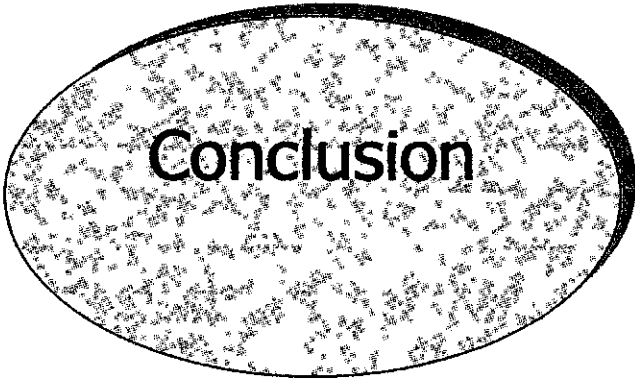
Hybridization was also attempted between, the species of three genera, viz. *catla*, *labeo* and *cirrhinus* of Indian major carps and the three species of Chinese carps belonging to the three genera viz., *Ctenopharyngodon*, *Hypophthalmichthys* and *Aristichthys*. In all,

nine intergeneric hybrids have been produced between Indian and Chinese major carps. Many of these hybrid progeny did not survive beyond one week excepting the catla-silver carp hybrids. However, high mortality of the hybrids at embryo and larval stages was observed in catla-silver carp hybrid too, up to the fourth day. Many of the hatchlings were deformed particularly at the caudal peduncle region. In one experiment, only three hybrids could be reared up to three months, while in another only 16 surviving hybrids could be reared for a period of over two months and they grew to a size of about 57.7 mm within this period (Ibrahim *et al.*, 1980).

The percentage of fertilization was reported to be very high, rearing from 82-100% (Ibrahim *et al.*, 1980). Morphologically, the hybrid had a comparable body growth to that of catla. The size of the head and scales, including the body color was similar to silver carp.

In the hybrid progeny resulting from the mrigal x grass carp cross, the complete process of embryonic development including cleavage, segmentation etc. was quite normal and the hatching rate was over 90%. However, the larvae gradually became abnormal with a bent body and died within eight days after hatching (Ibrahim *et al.*, 1980).

C H A P T E R = 4



Conclusion

Chapter 4

Conclusion

Genetics is new discipline of science and fish genetics is more so. Examples of genetical manipulations for improvement of fish are not many in the world. The general situation is such that the application has been more in those groups of fish, which have been the subjects of different biological studies. With time pass on and with the improvement of understanding of the biology, methodology and concept of hybridization are being applied to more and more conventional species. And for this it is found that carp hybridization has got emphasis.

Genetic selection and hybridization of the cultivated species of carp have to be undertaken with a view to evolve strains which have quicker growth rates, higher fecundity, earlier maturity, better taste and nutritional qualities, more efficient food conversion, and more resistant to unfavourable environmental conditions, diseases and parasitic infections.

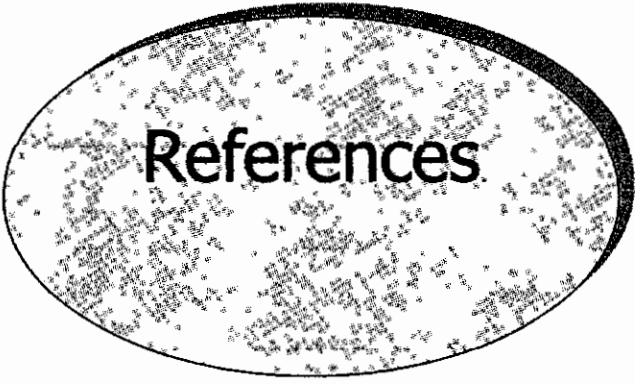
Progeny testing should follow every programme of hybridization. This involves the estimation of breeding worth on the basis of the performance of the offsprings.

Since both fertility as well as induced sterility in hybrids is of vital importance in fish culture, more stress should be given to the study of genetic causes of sterility and reduced fertility in hybrids. Prevention or control of reproduction for proper stock manipulation in the cultivated varieties of fishes, which readily reproduce in ponds, is no less important than making the difficult-to-spawn fishes spawn, or, improving the stock by genetic selection and hybridization. Since this aspect of research has received very little attention

not only in Asia but also in most of the other parts of the world, it is suggested that this particular aspect of fish culture should receive due attention of all fish culturists.

The hazards of indiscriminate hybridization cannot be overstressed. Fish culturists should be very cautious in their selection and hybridization programmes and see that worthless hybrids are not propagated.

CHAPTER 5



References

Chapter 5

References

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