Improper fish breeding practices and their impact on aquaculture and fish biodiversity

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Indian major carps (IMCs) namely, *Catla catla* (catla), *Labeo rohita* (rohu), and *Cirrhina mrigala* (mrigal) are fast-growing fishes cultured widely in freshwater bodies of India. Increased availability of seeds of these fishes by artificial spawning developed in late fifties[1], improved husbandry practices and mixed farming due to their compatibility and different feeding habits have established pisciculture as a profitable business in the last two decades. As a result, inland fish production substantially improved from 0.9 million tonnes in 1977–78 to 1.54 million tonnes in 1990–91.

Induced breeding of IMCs is a great landmark in the aquaculture development of India. This technology was transferred to fish farmers, who applied it to produce carp seeds in a large scale. But, due to the lack of primary training on fish genetics and awareness of basic genetic implications on the part of the farmers the breeding programme has largely remained an empirical practice. Though it is well known that meticulous breeding strategy and genetic selection programme help to increase yield, improve feed efficiency and reduce the duration for production, Indian aquaculture programme is practically untouched by the advanced selective breeding strategy. The application of selective breeding along with proper feeding and management helped improving productivity in Norwegian trout by about 60 to 70% in 15 years period[2]. Unfortunately, in India, in lieu of genetic improvement of fish stocks, the faulty breeding practices like mixed spawing, use of low number of spawners for breeding without considering the ratio of male and female breeders are practised in carp hatcheries. The thoughtless and unjudicious ways of fish breeding are likely to affect the 'gene pools' of these prized food fishes badly. The possible adverse effects of these empirical breeding practices are focused here.

Mixed spawning

Mixed farming (also called as polyculture or composite fish culture) of IMCs is a customary practice ommended by the fishery scientists for obtaining high production per hactare of water bodies. This naturally prompts the fish farmers to ask the fish breeders to supply fish seeds of these species in a desired proportion. For example, if catla, rohu, and mrigal are the only components of mixed farming, the recommended proportion of seeds in these species is 30, 60 and 10 respectively[4].

Artificial breeding of these fishes is generally done in modern farms in a specially designed 'breeding pool', by injecting crude pituitary extract or other such inducing agents to the brooders. Ideally, these species should be bred separately in rectangular breeding chambers of net ('hapa') suspended in a pond (Figure 1*a*) or in 'breeding pools' (Figure 1*b*) and the seeds released to the rearing ponds in a desired proportion. But, in some major fish farms of West Bengal (the state which contributes about 70% of the carp seeds of the country), catla, rohu and mrigal are bred simultaneously in the same breeding pool. The ignorant (or unscrupulous!) fish breeders practice 'mixed spawning' for the sake of their convenience and profit.

Mixed spawning leads to hybridization inadvertently. These species produce intergeneric hybrids in nature[3] and under captive breeding[4]. The identical chromosome number[5], identical isozyme gene expression[6], conserved nature of some genetic markers[7] and the ease of producing F_1 hybrids in a large scale[4] indicate their close phylogenetic kinship. Moreover, the F_1 hybrids are fertile. The breeding of an F_1 hybrid female of *C. mrigala* × *Labeo calbasu* with catla male and also their parent species to produce viable F_2 offsprings is an excellent example of hybrid fertility of carps[4]. All these suggest that the reproductive isolation is not stringently developed in these species. The external factors like geographical, ecological, developmental and/or behavioural rather than genetic factors are more responsible in preventing interbreeding in these species under natural conditions.

a *b*

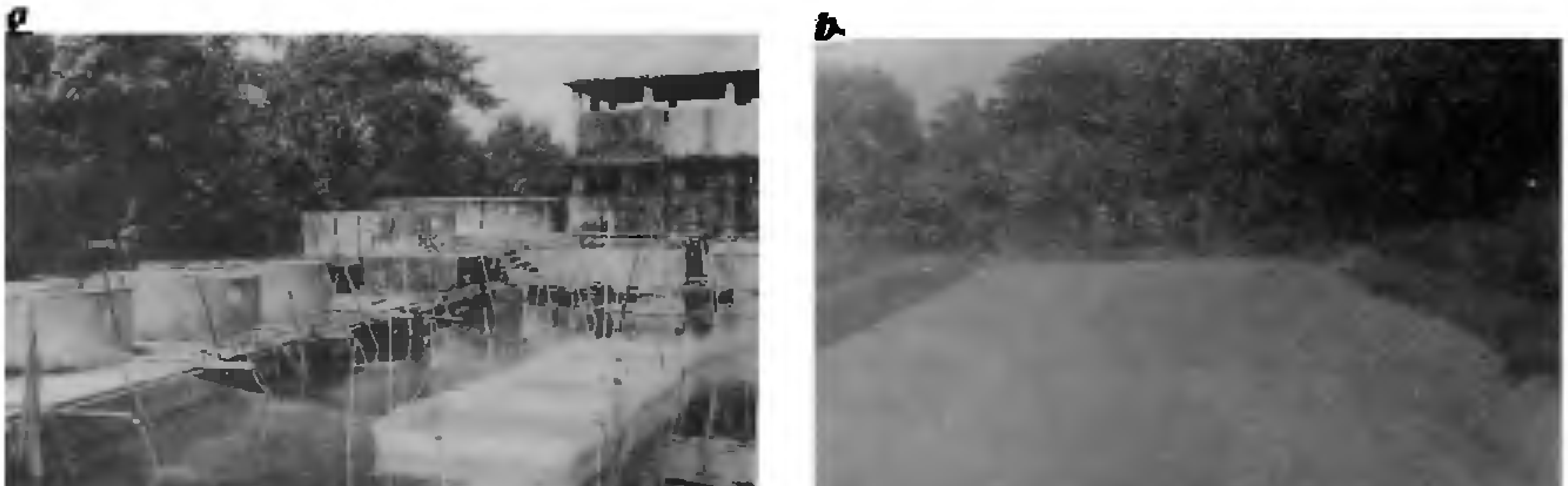

Figure 1. *a*, Nylon 'hapas' suspended in pond. In the upper left three chinese hatcheries are seen. *b*, A view of breeding pool.

Hybridization is more frequently observed in fishes than any other group of vertebrates. External fertilization and genomic plasticity[8] are attributed to be the causes of hybridization in fishes occurring in nature. In mixed spawning practice, synchronization of spawning time of these carps occurs due to hormonal stimulation, which increases the frequency of incidence of hybridization. The eggs of these species have identical characteristics: transparent, non-adhesive and non-floating. Duration of hatching of zygotes is also similar (16 hours at 26°C). Thus, the practice of mixed spawning increases the incidence of hybridization.

Hybrids of these fishes are not much useful from cultural point of view. Reciprocal hybrids of catla × rohu were evaluated by several authors[9]. The progeny of the cross between male catla and female rohu grew smaller than catla but larger than rohu. But they have higher flesh content than catla whose bigger head size reduce the actual flesh content. This is the only hybrid among all the crosses and reciprocal crosses having a cultural trait of limited beneficial use while others did not show any improved cultural traits[4].

Inadvertent hybridization among IMCs and backcrossing of F_1 hybrids with parents would cause genetic introgression among these fishes, causing contamination of gene pools of these prized food fishes. Genetic introgression is a very subtle phenomenon to document, which requires intensive study in population biology. Moreover, the long generation time (these fishes mature at two years of age) of IMCs requires long-term sustained effort in experimentation to study this phenomenon. Genetic introgression was demonstrated in the hybrids of tilapia[2] and Cutthroat trout[10].

Experience with purposeful hybridization without further care between hybrid progeny and their parents created several problems. The hybridization of the domestic common carp (*Cyprinus carpio*) with its wild living ancestor, the wild carp, was conducted in the erstwhile USSR and several other Eastern European countries. And these resulted in contamination of the wild carp and domestic carp brood stocks and in the deterioration of their economically important traits[11]. Another sad example is the hybridization of the *Acipensor sturio* (giant sturgeon or beluga) and *Acipenser ruthenus* (sterlet). First generation hybrids which were called besters possessed useful properties; from the beluga they inherit the ability to grow rapidly and from the sterlet the ability to live and to feed in freshwater basins[12]. Unfortunately, the hybrids were released in large quantities into rivers, lakes, estuaries and artificial reservoirs. This resulted in considerable contamination of the sturgeon stocks[11].

Inbreeding and genetic drift

Indian major carps have high fecundity, producing about 0.25 million eggs per female per breeding season. Thus, by breeding limited number of brood fishes a large number of offsprings can be raised. Generally, some of these offsprings are maintained for reproduction in subsequent years, whose offsprings later would breed in the same farm. So, the carp hatchery is virtually closed to genetic exchange with wild stocks[13]. Consequently, mating occurs among closely related individuals, causing inbreeding. Inbreeding was measured in some carp hatcheries in southern India[13], which ranged between 2% and 17% but a detailed study on inbreeding is lacking.

Inbreeding is a cumulative phenomenon. The effects of inbreeding on some salmonids and common carp (*Cyprinus carpio*) have been studied[14]. One generation brother-sister mating in rainbow trout resulted in increased fry deformity (37.6%), decreased food conversion efficiency (15.6%) and fry survival (19%). A single cycle of full-sib mating of common carp resulted in 10–20% depression of growth rate and a considerable number of individuals with abnormalities. This would reduce the aquaculture productivity[14].

Crude pituitary extract still forms a major inducing agent in artificial breeding programme. This has a drawback of not being able to cause ovulation in all the female brood fishes due to varied potency. As a result, the actual number of breeding population is decreased. Moreover, a low number of individuals are used as the founder population, where due to sampling (error) some alleles may not be represented, resulting in genetic drift. The loss of alleles reduces genetic variance in a gene pool. The adverse effects of genetic drift was felt in Auburn University, USA. Genetic drift robbed AU-Ivory Coast strains of *Tilapia nilotica* of all the genetic variance for increased growth rate and a strain of channel catfish (*Ictalurous punctatus*) (AU-RG-I) got extinct[15].

Stock integrity and genetic biodiversity

Spurt in commercialization of fish seed trade has resulted in transport of fish seed from one region to another for culture purpose. Since it is not so easy to keep aquaculture stocks segregated from the wild stocks, unlike the herds of land animals, the cultured stocks would likely escape to natural waterbodies during rainy season and hybridize with wild stocks to cause 'genetic intermixing' affecting 'genetic diversity'. Moreover, the aquaculture stocks are often recruited in the reservoirs and rivers arbitrarily to augment fish production without considering their geographical origin. Consequently, the native and the recruited stocks may hybridize causing genetic intermixing, leading to genetic homogenization in the long run.

These points need serious attention, when the natural fishery is declining in size and distribution due to over-exploitation, pollution load, habitat modification, damming of rivers, etc. The carps in the Ganges, Hilsa in Hooghly, Mahaseer in upper reaches or rivers have declined in recent years[16, 17]. This is alarming since the obvious consequences would be the reduction of genetic diversity, which would greatly affect the future breeding programme.

Need of objective study

Population genetic studies of commercially important species like IMCs in their different geographical territories by using modern techniques like restriction fragment length polymorphism (RFLP) of mitochondrial DNA and genomic DNA[18, 19] would help to document the genetic biodiversity and drawing up a 'genetic resource map'. This map would be useful in devising effective strategy for conserving genetic biodiversity and for selective breeding programme in aquaculture.

The breeding strategy should be developed in carps which would take into account the determination of the 'effective population size' for reducing the inbreeding and genetic drift. The use of cryopreserved spermatozoa in breeding programme can mitigate these problems. Fortunately, the technique of sperm cryopreservation in catfishes is available[20] and in carps it is under trial in CIFA, Bhubaneswar[21].

The genetic consequences of mixed spawning of catla, rohu and mrigal should be assessed under experimental conditions and by surveying the natural populations. The problems of stock contamination due to genetic introgression should be addressed with subtle tool of isozyme and DNA polymorphism[22].

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Acknowledgement: B. K. P thanks DBT, New Delhi for a fellowship.

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