# Carp Brood Stock Management and Genetic Improvement Programme under Fourth Fisheries Project

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**Abstract**

Bangladesh is rich in terms of globally important wetland ecosystems and associated aquatic biodiversity. The total area of inland waters is estimated at 4.3 million ha. These inland water habitats form the largest floodplains in Asia, widely considered to be one of the most important wetland complexes in the world. This rich biological diversity – including genetic, species, as well as habitat diversity - has been formed over millions of years. The evolution of habitat diversity has resulted from erosion of the Himalayas and tectonic movements, followed by successful adaptation of fish species to the slow changing of habitat, based on their genetic diversity. This ancient adaptive capacity of fish species has been seriously affected over just the last twenty years, not only through habitat degradation, but also through the use of inappropriate artificial reproduction and fish culture practices. The large-scale induced breeding operations by over 600 private hatcheries have raised concern about potential genetic degradation of cultured endemic and exotic species. Mainly due to a lack of technical knowledge and awareness of the potential ecological consequences, widespread inbreeding depression, negative selection and genetic introgression by hazardous hybridisations has and continues to occur. The increasing use of culture-based

fisheries in the open-water floodplains through the mass release of fingerlings has also endangered the genetic purity of wild endemic fish populations.

As this ecological issue is relevant to those in many other floodplain areas in the region, the Global Environment Facility (GEF) funded ‘Aquatic Resources Development, Management and Conservation Studies’ project is presently conducting studies to design a programme for genetic diversity improvement and the maintenance of appropriate broodstock lines. This paper is a brief presentation of the proposed studies which are just starting implementation.

## Introduction

The Fifth Five Year Plan of Bangladesh is targeting 1.675 million tons of fish production from inland fisheries for the year of 2001/2002. The achievement of fish production in the year of 1999/2000 was 1.321 million tons, while the per capita annual fish intake was 12 kg instead of the required 18 kg. The aquaculture needs for fish fry are almost entirely (98.6% according to FRSS/DoF, 1999/2000) provided by hatcheries. Consequently the achievement of aquaculture targets in the immediate future will be determined by the genetic status of hatchery broodstock. In the recent past, inexperienced hatchery operators have damaged most of the broodstock through improper management, resulting in considerable genetic degradation. While induced breeding is practised, limited numbers of artificially selected breeders are involved; their success of reproduction is forced by hormone injections. The survival of the larvae and fry is promoted by providing highly artificial conditions, including the use of chemicals and selective insecticides to control predators. This results in the complete absence of natural selection, whose selective process in natural conditions eliminates traits of reduced vitality, slow growth rate, reduced resistance to diseases, etc. For this reason, the production potential of the Bangladeshi closed waterbodies and stocked floodplains are increasingly constrained.

The establishment of improved fish breeding systems is a considerable task, as the majority of hatcheries are affected by genetic degradation, with more than 4000 hatchery owners and nursery operators involved. Further training and establishment of an adapted legal framework is urgently required to improve genetic knowledge and increase awareness about the responsibility of hatchery operators. By improving and controlling the quality of broodstock and breeding activities in hatcheries, aquaculture productivity will be improved and the impacts on capture fisheries biodiversity reduced.

Under the Fourth Fisheries Project, the GEF financed ‘Aquatic Resources Development, Management and Conservation Studies’ will design and test appropriate methods for improvement and provide training. Based on these studies, the project will assist the DoF to design a strategy and Action Plan for ensuring the genetic integrity of hatchery stocks for aquaculture and culture-based open water stocking.

### Study 1: Genetic Status of Endemic and Exotic Broodstock

#### 1.1. Objectives

- Quantify the declining genetic pool of hatchery brood stock including inbreeding, negative selection, genetic drift, genetic introgression and decline of performance of improved strains.
- Identify likely genetic damage of the endemic population by mass stocking of floodplains by fingerlings coming from domesticated stocks.
- Assess the extent of damage caused by introgressed silver carp on national fish production.
- Assess findings to prepare a proposal for a framework to control hatchery brood stock management, breeding activities, nursery management, and quality control of hatchery products for pond culture, as well as for floodplain stocking.
- Report on genetic status of domesticated and wild stock and propose a framework for their control.

#### 1.2. Declining Gene Pool of Cultured Aquatic Organisms

In Bangladesh there has been a long-term decline in genetic diversity through a reduction in habitat availability, but is more recently threatened by the rise in aquaculture production. In Bangladesh the large-scale breeding operations started by rapid expansion of hatcheries from 1980. The number of fish hatcheries in 2000 has reached 744, consisting of 113 public and 631 privately owned units. Their production of 4 to 5 days old fry was 184,343 kg (Fisheries Recourses Information of Bangladesh, 1999-2000), while the quantity of fry collected from natural sources was significantly reduced from about 20,000 kg in 1980 to 2,683 kg in 2000.

The significant increase in hatchery production has improved the availability of fry for culture. This has contributed to protection of wild stocks, as the price of hatchery-produced fry has dropped, while the availability of fry in the wild is reduced. Moreover, there is a serious concern about the genetic erosion of hatchery brood stock. Not less than 9 – 10 generations of Indian Major and Chinese carps and as many as 18 – 20 generations of common carps have been used for induced breeding from the private hatcheries. Proper selection has not been maintained, resulting in the use of undesirable small size breeders. Closely related stocks have been repeatedly used over many generations, and hazardous hybridization has been conducted in many hatcheries (Hussain and Mazid, 2001).

The danger of genetic degradation is extended to the wild stocks too. Although natural hybridisation accidentally occurs among Indian carps (Desai *et al*. 1970, Khan *et al*. 1989), these are usually eliminated through natural selection. On the other hand, a strong negative effect can be expected on the wild stocks by mass introduction of domesticated, genetically degraded stocks, as fingerling releases in floodplains, and large scale escapes of cultured stocks due to increased flooding.

### 1.3. Main cultured carp species in Bangladesh:

**Catla** ***(Catla catla):*** Catla is the fastest growth species among Indian Major Carps. It is an inhabitant of the rivers of Bangladesh, India, Pakistan and Myanmar (Jhingran and Pullin, 1985).

**Rohu (*Labeo rohita):*** Rohu is not as fast growing as catla, attaining only 500 g after one year under natural riverine conditions. "Red rohu" has been produced in some hatcheries in Jessore, by fertilizing rohu eggs with red common carp male. The phenotype of the hybrid is rohu, except the colour is red. [Shardar, A.S. personal communication 1999). A fertile hybrid of rohu-Calabash was also produced, as well as their F1 and F2 hybrids (Krishnaja and Rege, 1979).

**Mrigal (*Cirrhinus cirrhosus):*** The mrigal is a slow growing species, reaching approximately 500 g in the first year under natural conditions It is possible to produce a fertile hybrid of mrigal and rohu (Naseem, 1971).

**Silver Carp (*Hypophthalmichthys molitrix):*** First introduced in 1969, with initial great success in semi-intensive composite culture, as its main food is phytoplankton. Countrywide, the stocks are affected by bighead carp introgression.

**Bighead Carp** ***(Aristichthys nobilis):*** Bighead carp were first imported from Nepal in 1981. Affected by genetic introgression from silver carp. Strongly compete with the native Catla.

**Grass Carp** ***(Ctenopharyngodon idella):*** First imported from Hong Kong in 1966 (Hussain and Mazid 2001), [DP1], and from ………..Stocks are affected by negative selection and inbreeding.

**Black Carp (*Mylopharyngodon piceus):*** Introduced in 1983 from China. It is a mollusc eater, performs well in ox-bow lakes. Due to the fact that a limited number of females have been reproduced successfully in Bangladesh, the present stock of black carp is probably genetically closely related, representing a risk of inbreeding.

**Silver barb *(Puntius gonionotus)*:** Silver barb was introduced from Thailand in 1977 (Hussain and Mazid, 2001).

**Common Carp (*Cyprinus carpio*):** Many common carp strains have been introduced to Bangladesh:

- The Chinese Big Belly**:** during its thousands years of culture, this variety has adapted to harsh culture conditions in still water, rather than being fit for living in rivers. This variety was introduced in around 1960 from China (Hussain *et al.* 2001). Other, unspecified scale carp varieties were introduced from India by farmers of Comilla and Jessore, in the early 1960s. A variety of scale carp, different from the Big Belly was found by the author in 1980 at Jessore farms.
- A genetically improved scale carp variety was imported from Vietnam in 1995 by BFRI Mymensingh through ICLARM (Hossain *et al.*, 2001). The origin of this variety is the geographically distinct Hungarian Scale carp strain of "Tata" (A. Woynarovich, personal communication).
- The date of introduction of Japanese red coloured carp *(Hi-Goi)* is not known, but the author observed this strain in Jessore private farms in 1980. This fish is red coloured, with some grey-black colour spread on dorsal scales just behind the head.
- Mirror carp *(Cyprinus carpio var. specularis)* was first introduced from Nepal in 1979 for the World Bank financed Raipur Fish Hatchery (Rahman, 1989). The origin of this mirror carp is Dinnyés, Hungary, from where the author sent fingerlings to an FAO project in Nepal, in 1973. In 1982 a high performance variety of mirror carp was imported for the World Bank's Oxbow Lakes-1 Project in Kotchanpur. This mirror carp was also developed in Dinnyés, by using German, Hungarian, Yugoslavian (Nasic) and Israeli strains. From this import only a few individuals were reproduced and spread to private hatcheries, which quickly resulted in inbreeding depression. In 1997, from the same origin, 700 mirror carp were reintroduced and are presently available in Parbatipur NFEP and in Natore FSMF. The mirror carp and the inbred local scale carp strain were maintained separately at Kotchanpur Central Hatchery Complex, to produce a heterosis hybrid, between 1983 and 1985. The hybrid had full scale covering, as it is a dominant characteristic. Its survival rate and growth rate was superior of that of the Mirror carp in the Oxbow lakes (baors).
- The Japanese Fancy carp *(Koi)* was introduced probably by the aquarium trade. This multiple coloured strain has been developed in Japan from the red coloured strain called *Hi goi*

Due to the fact that the Bangladeshi common carp stock is a result of recent mixing of many varieties by unskilled hatchery operators, it has a maximum genetic diversity in comparison with pure strains. For this reason the question of inbreeding does not arise in most of the cases, but stocks are affected by negative selection.

**1.4. Issues**

Genetic erosion of domesticated stocks: without appropriate broodfish management, the long-term decline of genetic quality was almost inevitable, allowing a high number of repetitions of management mistakes for each generation. In an unidentified number of hatcheries, improper management resulted in the decline of the genetic pools of reproduced populations of both endemic and exotic species as follows: (i) proper selection of breeders has not been maintained; (ii) closely related and small stocks have been repeatedly used generations after generations resulting in inbreeding, genetic drift and reduced resistance to diseases; (iii) negative selection was made for smaller sizes at sexual maturation; (iv) failure to follow selection criteria for improved varieties of Mirror carp, GIFT tilapia resulted in loss of improved performance, (v) hazardous hybridisations were made resulting in genetic introgression of several species.

Hatcheries without broodstock ponds: a recent practice is for hatcheries not to keep broodstock, but to procure early matured, undersized "breeders" from fishermen on the day of reproduction. The spent breeders are sold dead immediately after operation.

Lack of knowledge of hatchery and nursery operators: from the beginning of the introduction of the hatchery system, little training has been given to hatchery and nursery operators on genetic issues of fish breeding, resulting in lack of knowledge and genetic degradation of farmed stocks.

Lack of knowledge on effects of openwater stocking on wild stock: during the last decade mass release of hatchery produced endemic fish fingerlings has been conducted. The mass release of domesticated stocks (particularly of genetically degraded stocks) reduces vitality and may irreversibly alter the gene pool of wild stocks. This activity is continuing on an increasing level, not only by the DoF but also by NGOs and the public. It is important for the future to know the effect of stocking on wild populations.

Lack of knowledge on genetic status of hatchery stocks: there is an immediate need for establishment a framework, to control the genetic fitness of hatchery stocks (license, fitness, pedigree) in order to prevent further damage to farmed and wild stocks.

Genetic Introgression of silver carp: silver carp are the cheapest of the carps to produce, as it mainly feeds from a primary production level, saving the energy which is lost during transformation of food to secondary and tertiary levels for feeding other fish species. As a result it has become one of the dominant species in reservoir and semi-intensive fish culture systems in Europe and Asia. The species has been hybridised with bighead carp by many hatchery operators. This introgression of silver carp species has probably contaminated the whole silver carp stock of Bangladesh, as the hybrid is not sterile. A similar situation exists in the Mekong delta (personal observation). This so called "silver carp" has an intermediate number of gill rakers and an intermediate length of digestive tube. As a result it can not feed from phytoplankton of smaller size range as pure strain does, feeding more on zooplankton. Thus results in stronger competition to catla, in comparison with the pure silver carp. The loss in potential productivity probably equates to a substantial economic loss.

## 1.5. Outputs

The study will provide the following outputs:

- Monitoring model for hatcheries and nurseries.
- Model for quality control of hatcheries, broodstock, progenies and nurseries established.
- Genetic status of wild populations of Indian Major Carps (IMCs) identified.
- Geographically and genetically distinct strains of IMCs identified.
- Better understanding on quantitative contribution of pure silver carp to Bangladeshi carp polyculture system.

## 1.6 Methodology

### *General Approach*

Firstly identification of the extent of genetic damage will be assessed through collection of information by enumerators. Information on degraded stocks will be confirmed by genetic analysis in BFRI/Stirling or other laboratories and field trials. Monitoring of hatchery and nursery farms will be made during the project period, in order to have data for preparation of standards on hatchery and nursery management techniques. This will help to formulate a draft Framework to control future activities of hatcheries and nurseries. Research will be carried out to investigate the genetic introgression of silver carp. A workshop will be organized to discuss the draft Framework, followed by preparation of final report on proposed framework which will be used for creation of the Action Plan.

### *Tasks and Activities*

Task 1: Establish present genetic status and culture practices of domesticated and wild stocks

Select research institute(s) for collaboration to carry out trial rearing of domesticated and geographically distinct wild stocks to identify i) existing distinct strains, (ii) likely negative effect of stockings, genetic analysis of domesticated and wild stocks, collection of spawn from hatcheries, stocking of spawn in trial ponds for test rearing up to adult stage (tagging), to compare growth rate and other parameters of different hatchery stocks.

Conduct baseline survey.

- List hatcheries and nurseries in the country:
- Genetic status of hatchery stocks
- Status of hatchery and nursery techniques
- Genetic status of wild stocks

Genetic analysis of wild stocks. Genetic analysis will be made to identify genetic degradation of wild stocks due to mass fingerling release of domesticated stocks.

- Collection of spawn from Padma, Jamuna and Halda rivers.
- Stocking of spawn in trial ponds for test rearing up to adult stage (tagging).
- Compare growth rate and other parameters of different stocks.
- Compare gene pool of indigenous species, from different geographic origin to find likely existence of distinct geographic strains
- Compare genetic pool of different phenotypic species of different geographic regions, to control likely negative effect of floodplain stocking on wild populations.
- Compile results for guidelines for floodplain stockings and for controlling framework preparation.
- Results will be used for guidelines for improvement of breeders and for controlling framework preparation.

Monitoring of hatcheries and nurseries. Conduct survey and checking breeder condition, purity, age and size, density, feeding rates and food ingredients, hatchery design, water supply system, water quality, incubators type, density in incubators, system to eliminate deformed larvae, use of harmful chemicals, first feeding of spawn, packing/transportation techniques of spawn. Visiting private nursery operators to follow up the performance of produced spawn, their nursing techniques, feeding, harvesting, conditioning and transportation.

Report. Assessment of monitoring, which will help to design framework to control hatchery and nursery operations.

Task 2: Framework to control Hatcheries and Nurseries

Establish standards. Assess hatchery and nursery monitoring data to establish standards for controlling framework proposal preparation.

Design framework proposal including:

- Pond criteria, management.
- Breeder selection criteria, management, distinct stocks.
- Maintenance and control of genetic diversity of breeders.
- Hatchery design criteria.
- Hatchery techniques criteria species wise.
- Fingerling rearing criteria for aquaculture and for floodplain stocking.
- Certificate of fingerling origin.
- Hatchery license species wise.

Workshop. Workshop to discuss proposed framework and strategy

Action Plan Development. Report on proposed framework as basis for the Action Plan

Task 3: Genetic degradation of silver carp.

Develop 'brood bank'. Collection of pure species of Silver carp and Bighead carp. Research on morphological and nutritional characteristics in collaboration with Stirling University. Find differences of genetic markers to identify pure species from their hybrids.

Evaluation. Evaluate silver carp versus bighead carp, with special attention to their contribution to national fish production and food competition in carp polyculture system. The report will be used to prepare the Action Plan.

## Study 2: Improvement of Broodstock Management Techniques

### 2.1.Objectives

<u>Overall Objective</u>

The overall objective of this study is contribution to establishment of improved fish breeding system by training and by providing guidelines for hatchery broodstock management, for the production of high quality brood stock in DoF and private hatcheries.

<u>Specific Objectives:</u>

The specific objectives of this study are:

- Designs and models for broodstock improvement of DoF and private hatcheries.
- Initiate testing of broodstock improvement models in selected farms.
- Training of nearly 100 trainers of DoF trained for genetic fitness maintenance of broodstock, hatchery and nursery management.
- Training of 631 hatchery owners and 3441 nursery operators by the trained DoF officers.

### 2.2.Outputs

This study will provide the following outputs:

1. Report on proposed framework for improved fish breeding system.
2. Testing of improvement models are initiated in selected hatcheries.
3. Selected hatcheries will demonstrate gene pool improvement and maintenance techniques.
4. 4000 hatchery and nursery operators trained in genetic diversity maintenance of cultured species.

### 2.3.Methodology

***General Approach***

The project will closely cooperate with the BFRI, Brood Bank project of the DoF and the development of 20 FSMFs under the FFP, as well as in Raipur Fish Hatchery and in private hatcheries in establishing improved quality broodstocks. Two types of broodstock will be initiated, one is a controlled domesticated stock of endemic and exotic species for aquaculture in closed waters, the other is wild broodstock of endemic species to produce fingerlings for flood plain stockings. The existence of geographically and genetically distinct wild populations of endemic species will be investigated and (if they exist) creation of broodstocks for each distinct strain will be proposed in order to provide appropriate quality of fingerlings for geographically distinct floodplain stockings. Selected hatcheries will be also used as models to test and demonstrate gene pool improvement and maintenance techniques. Based on findings of genetic analysis under the baseline survey, mating designs will be prepared for the selected hatcheries.

***Tasks and Activities***

<u>Task 1: Select Model hatcheries</u>

Select DoF and private hatcheries and train collaborators

<u>Task 2: Mating designs</u>

Line crossbreeding design, exchange of breeders, collecting milt from wild to increase gene pool of hatchery stocks and replacement of broodstock.

<u>Task 3: Improvement of hatchery management techniques</u>

Assess results from surveys, training of 631 hatchery operators and 3441 nursery operators

<u>Task 4: Experimental production of monosex female common carp</u>

For stocking common carp in floodplains, it may be possible to produce monosex female fingerlings. Female common carp grows approximately 15-30% faster than males do; in addition there is a reduced risk of its reproduction and establishment in the wild. Neomale fingerlings will be produced in collaboration with BFRI and distributed to selected FSMF's for all female fingerling production.

<u>Task 5: Action Plan.</u>

Prepare Action Plan on maintenance of genetic diversity in aquaculture and in Gangetic floodplain-riverine ecosystem.

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[DP1]According to Hussain and Mazid (2001), grass carp were first introduced in 1966 from Hong Kong.