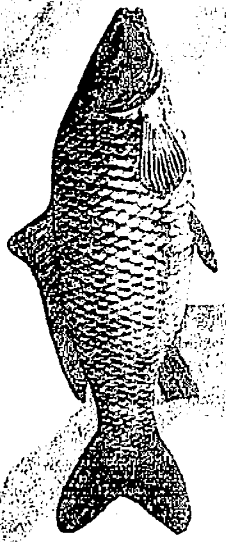
Proceedings of the Planning Workshop for Genetic Improvement of Carp Species in Asia



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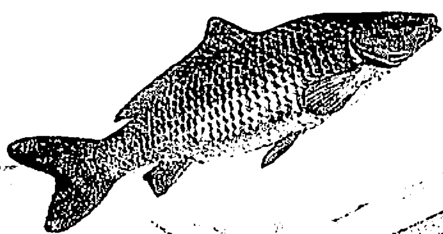
26 - 29 July 1997

ICLARM
International Center for Living Aquatic Resources Management

Asian Development Bank

International Network on Genetics in Aquaculture



PROCEEDINGS OF THE COLLABORATIVE RESEARCH AND TRAINING ON GENETIC IMPROVEMENT OF CARP SPECIES IN ASIA

Central Institute of Freshwater Aquaculture
Bhubaneswar, India
26-29 July 1997

Edited by:

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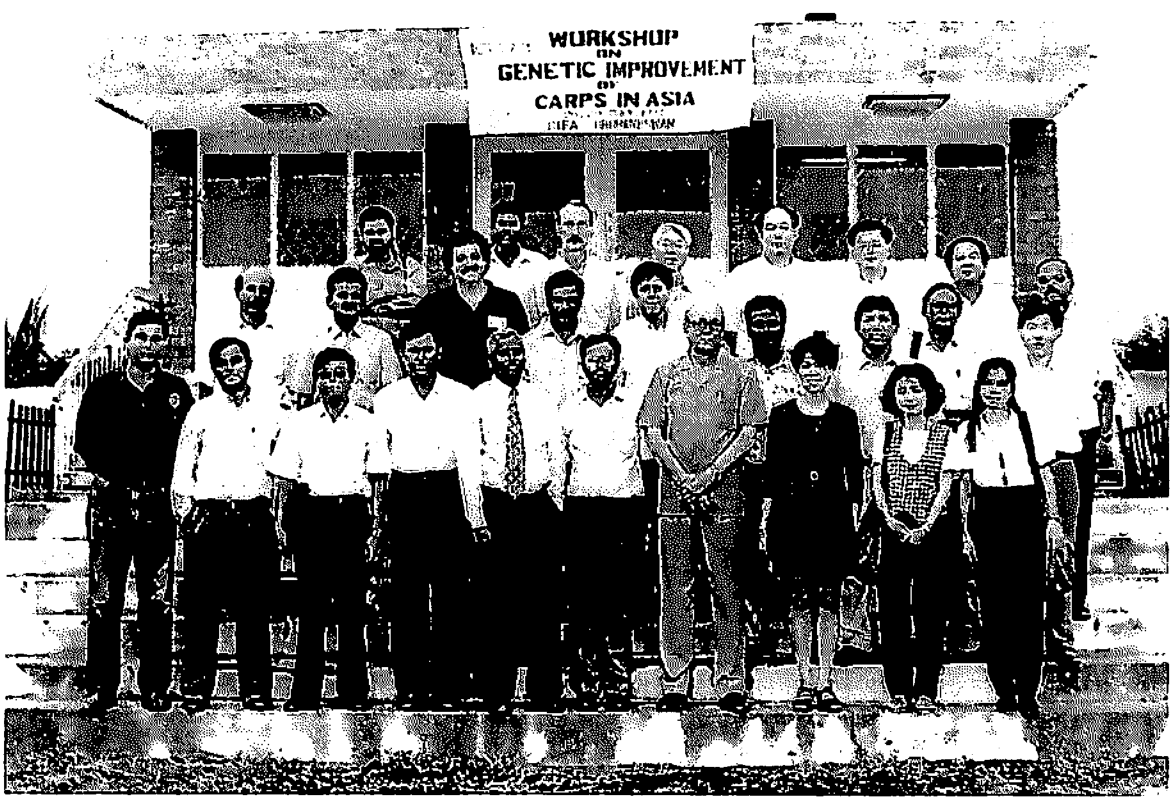
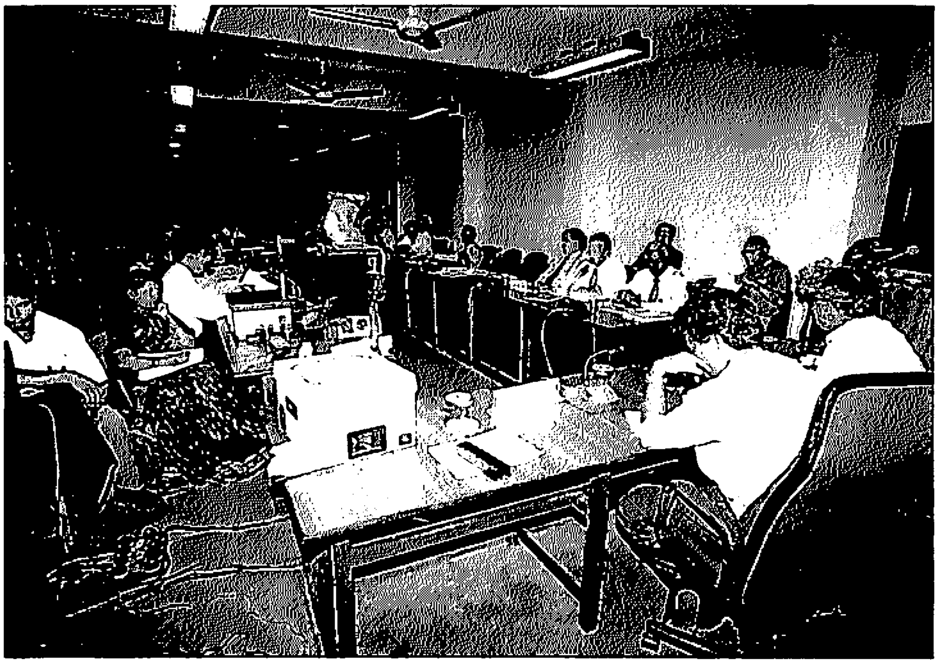
Dr. Modadugu V. Gupta addressing the participants during the opening ceremonies. Honorable J.B. Patnaik, Chief Minister of Orissa State (sitting third from left) inaugurated the meeting. (Sitting from L-R) Dr. S. Ayyappan, Director of the Central Institute for Freshwater Aquaculture, Dr. M.Y. Kamal, Assistant Director General of the Indian Council of Agricultural Research, Dr. Peter Gardiner, Deputy Director General of ICLARM and Mr. Abhay Rath, Principal Secretary of Fisheries, Orissa State.



Participants of the Planning Workshop for the Genetic Improvement of Carp Species in Asia Project held during 26-29 July 1997 at the Central Institute of Freshwater Aquaculture, Bhubaneswar, Orissa, India



Participants engaged in discussion in one of the sessions of the workshop.

Participants visit the aquaculture facility at the Central Institute for Freshwater Aquaculture (CIFA)

COLLABORATIVE RESEARCH AND TRAINING ON GENETIC IMPROVEMENT OF CARP SPECIES IN ASIA

1. INTRODUCTION

Recognizing the importance of genetic improvement to increase and sustain aquaculture production, the Asian Development Bank (ADB) and the United Nations Development Program (UNDP) provided financial support to the International Center for Living Aquatic Resources Management (ICLARM) and its partners in 1988 to conduct a collaborative aquaculture research project on the Genetic Improvement of Farmed Tilapia (GIFT). Within four years, the GIFT Project had developed a genetically improved Nile tilapia *(Oreochromis niloticus)* breed that outperformed the most widely cultured Nile tilapia strains in the Philippines. Following the GIFT Project, ADB provided another Technical Assistance Grant (RETA No. 5558) in 1993 to carry out the Dissemination and Evaluation (of genetic, socioeconomic, and environmental aspects) of the Genetically Improved Tilapias in Asia (DEGITA) in five developing member countries (DMCs) of the Bank (Bangladesh, People's Republic of China, Philippines, Thailand, and Vietnam).

Encouraged by the impressive results of the GIFT and DEGITA Projects and prompted by the urgent need for the genetic improvement of cultured stocks of carps, scientists representing the carp producing countries of Asia (Bangladesh, India, Indonesia, People's Republic of China, Thailand, and Vietnam) got together during the Second Steering Committee Meeting of the International Network on Genetics in Aquaculture (INGA) held in Hyderabad, India in 1995, and discussed the needs and priorities of carp research. They recommended to ICLARM to immediately initiate a GIFT-type strategic research and training initiative on Asian carps. In response, ICLARM developed a proposal for the consideration of ADB. The complexity and time requirement of the carp genetic research require a two-phased project. During Phase I, the focus is on determining research priorities and initiating research leading to the development of high yielding breeds and strains. Phase II will concentrate on (i) the continued development of improved breeds, (ii) dissemination and evaluation of improved carp species, and (iii) establishment of national carp breeding programs.

The ADB provided a Technical Assistance Grant (RETA No. 5711) to ICLARM for implementing the first phase of the Project. Six countries: Bangladesh, People's Republic of China, India, Indonesia, Thailand and Vietnam are the participants in this project. The first phase of the project which became operative on 01 June 1997 will be implemented over a period of 36 months.

The objective of this project is to assist the six major carp producing countries to increase food fish production and to improve the nutrition and income of small-scale fish farmers by developing genetically improved carp breeds with sustainable productivity. Specifically, the project will establish research priorities for carp species, farming systems, and breeding strategies, and will conduct strategic research and training activities on the basis of these priorities.

The Phase I of the project will (i) assess the current status of carp genetic resources in Asia, including their systematic documentation and evaluation, (ii) gather the existing technologies and experience on carp culture and breeding in Asia; (iii) establish strategic research partnerships and networking arrangement; (iv) develop criteria for prioritizing carp genetic research; (v) identify research priorities and approaches, including species, farming systems, and breeding strategies; and (vi) initiate and conduct location-specific strategic research and training based on identified research priorities in carp genetic improvement leading to the development of high-yielding carp strains.

2. PLANNING WORKSHOP

To spin-off the activities of the Project, ICLARM organized a planning workshop at the Central Institute of Freshwater Aquaculture, Bhubaneswar, India during 26-29 July 1997, attended by representatives and scientists of the six-participating countries and of ICLARM. The specific objectives of the planning workshop were: to review existing information on carp species; to discuss and unify research methodologies of the Project and to finalize workplans and implementation schedules of the six-participating countries. The program of activities undertaken and the list of participants during the planning workshop are in Appendices 1 and 2, respectively.

The planning workshop had five technical sessions: 1) Carp genetic resources in Asia; 2) Current status of carp genetic research and breeding practices in Asia; 3) Socioeconomic issues related to carp industry in six-participating countries; 4) Research methodologies and development of workplan outlines; and 5) Development of country-specific workplans. Papers and discussions for each technical session are summarized and presented in the following section of this report.

3. CARP GENETIC RESOURCES

This section provides the summaries of the papers and discussions on the carp genetic resources in participating countries.

All the countries participating in the project have vast carp genetic resources, which are an important element of the aquaculture production systems. In view of this, attention is being paid in recent years for their conservation and utilization. The details of carp genetic resources in different countries are presented hereunder. The detailed reports for each country are in Annex 1.

3.1. Bangladesh

Bangladesh, a riverine country, with major rivers Padma, Jamuna, Meghna, Brahmaputra, and Tista is blessed with vast aquatic resources. Inland aquatic resources comprising floodplains, rivers and estuaries, oxbow lakes, ponds, cover an area of 4,459,692 ha. The country is rich in the diversity of fish species, with 296 freshwater and brackishwater fish species (including freshwater prawns) and 511 marine fish species (including marine shrimps), many of which are important for aquaculture and capture fisheries.

Indigenous carps, which are the main species for aquaculture, are represented by six genera, with thirteen species. They are divided into two groups: major carps, represented by catla *(Catla catla)*, rohu *(Labeo rohita)*, mrigal *(Cirrhinus mrigala)* and calbasu *(Labeo calbasu)* and minor carps of which the important are *L. bata, L. gonius, L. nandina.* Besides these, the giant carp, mahseer (*Tor* spp.) and barbs *(Puntius* spp.*)* are important genetic resources.

In addition to the above mentioned indigenous carps, a number of exotic carps were introduced into Bangladesh for aquaculture. Among them are: silver carp *(Hypophthalmichthys molitrix)*, bighead carp *(Aristichthys nobilis)*, grass carp *(Ctenopharyngodon idella)*, black carp *(Mylopharyngodon piceus)*, common carp *(Cyprinus carpio)*, mahseer *(Tor putitora)* and silver barb *(Puntius gonionotus)*. All these indigenous and exotic carps are used in polyculture in ponds and some of them are also stocked in floodplains, rivers and reservoirs, for enhancing the natural fisheries.

Since late 1970s, production of seed through hypophysation has become a common practice in over 400 hatcheries in the country and some 31 billion hatchlings are produced annually. Deterioration in hatchery bred stocks, as amplified by retarded growth, morphological deformities, increased incidence of disease, has been observed in recent years due to poor brood stock management. It is feared that stocking such hatchery bred stocks in floodplains and rivers might lead to loss of genetic variation and cause introgression.

Degradation of aquatic environments as a result of natural and human induced changes, is endangering a number of endemic species.

3.2 China

There are about 3,016 species of fish in China, of which 800 are from freshwater. Carps play a significant role in both capture fisheries and aquaculture. Some 22 species of carps are used in aquaculture. Eighty percent of aquaculture production is contributed by ten species. Silver carp, bighead carp, grass carp, common carp, crucian carp *(Carassius auratus)*, wuchang fish, black carp *(Mylopharyngodon piceus)* and mud carp *(Cirrhina moliterella)*, and blunt snout bream *(Megalobrama amblycephala)* are the main species used in aquaculture. Silver carp, bighead carp, grass carp and black carp, together known as 'four Chinese farmed fish' contributed 6.719 million tons to aquaculture production in 1994. Silver carp, grass carp and black carp are distributed in the Yangtze, Pearl and Amur Rivers, while bighead carp is distributed in Yangtze and Pearl Rivers. Seven stocks of farm originated Chinese carps have been established in the Yangtze River basin. Common carp is the most domesticated species in China and many strains/varieties have been developed. Three subspecies of crucian carp are cultured and ploidy level, body shape and production traits vary among subspecies and strains.

Aquatic biodiversity in China is under stress and it has been estimated that some 98 fish species are either extinct, endangered or threatened. Conservation of fish genetic resources in Yangtze River has been given a high priority considering that they account for 60% of the total freshwater fish production in China.

Twenty four national farms for wild and domesticated aquatic organisms have been established to maintain and produce better brood stock.

3.3 India

Carps are an important component of India's rich fish biodiversity and not only that they support the inland capture fishery, but also contribute substantially to aquaculture production. The four major carps which contribute substantially to aquaculture production belong to three genera: *Catla, Cirrhinus* and *Labeo*. The important species belonging to this genera are: *Catla catla, Cirrhinus mrigala, C. reba, Labeo rohita, L. calbasu, L. dero, L. dyocheilus, L. fimbriatus, L. kontius, L. bata and L. gonius.*

Chinese silver carp and grass carp and different strains of common carp have been introduced into India and formed an important component of polyculture of indigenous and exotic species. Bighead carp and black or snail carp *(Mylopharyngodon piceus)* have found their way into India in recent years.

Displacement of wild stocks and high levels of introgression as a result of large-scale introduction of hatchery stocks has been reported. Studies in some species have clearly indicated that the hatchery stocks differ greatly from wild stocks.

Some minor carps like *Labeo dero, L. dussumieri, L. fimbriatus* and *L. gonius* are on the endangered species list. Many of the endangered carps are from peninsular region and some are endemic only to India. Major carps are not endemic to peninsular region and have been introduced and their introduction could be one of the reason for endangering indigenous peninsular carps. While the major carp species are not either endangered or threatened, they are prone to loss of genetic diversity and variability due to extinction of genetically distinct wild populations, escape and ranching of farmed seed and competition from exotic carps.

Information on population biology and life history traits is lacking for many important aquaculture species of India. Cataloguing of available biological and genetic information is in progress.

3.4 Indonesia

Common carp is the most important cultured species in Indonesia. Environmental conditions and farming systems differ from region to region and with this, common carp also exhibits variation in body color and color pattern on the body. Some well established stocks were selected on the basis of color and given specific names, such as "Merah" (red) developed by farmers in East Java, "Majalaya (dull green) in West Java," "Sinyonya (yellow) and Punten (dark green)". All stocks have been hybridized under farm conditions. Geographical barriers may have split common carp stocks into several sub-populations, among which gene flow is restricted.

Grow-out farmers prefer dark colored morphs, especially green, because of their better survival, larger size at maturity, faster growth and better disease resistance. Characterization of 21 collections of common carp from various isolated areas, was carried out.

3.5 Thailand

Family Cyprinidae which covers most of the scaled fishes of Thailand has 55 genera and more than 200 species. Most of them are economically important for aquaculture, inland capture fisheries, as well as for stocking reservoirs.

The indigenous species used in aquaculture are: silver barb *(P. gonionotus)*, jullien carp *(Probarbus jullieni)*, Jullien's mud carp *(Cirrhinus jullieni)*, soldier-river barb *(Cyclocheilichthys enoplos)*, *Leptobarbus hovenii*, *Catlacarpio siamensis* and *Osteochilus hasselti*. Of these, *P. gonionotus* is the most important and widely cultured species in ponds and rice fields.

In addition to the indigenous species mentioned above, eight species of carps have been introduced into Thailand and used in aquaculture. They are: common carp, Chinese carps: silver carp, bighead carp, and grass carp and Indian carps: rohu, mrigal and catla.

Due to programs undertaken for restocking of reservoirs and other natural waters, genetic contamination of natural populations from hatchery populations was noted. Spatial genetic structure of *P. gonionotus* populations was studied. High genetic variability was observed in 12 natural populations from three rivers and 29 hatchery stocks from different regions of Thailand were studied. Allozyme data indicated three strains of common carp in Thailand.

3.6 Vietnam

Freshwater fish fauna of Vietnam comprises of 544 species under 228 genera. Of these, only 11 species are common to the north and southern parts of Vietnam. About 50 carp species are economically important. About 28 indigenous fish species are being used in aquaculture production systems, of which 9 species are native to the North, 14 species native to the South and 5 species distributed in both the regions. Thirteen species of carps are widely used in aquaculture. These are: common carp, Vietnamese silver carp *(Hypophthalmichthys harmandi)*, black carp, mud carp, *Squaliobalbus curriculus*, *Megalograma ferminalis*, *Spinibarbichthys denticulatus*, *Carassius auratus*, *P. gonionotus*, *Leptobarbus hoeveni*, *Puntius altus*, *Puntioplites protozysron* and *Osteochilus hasselti*.

In addition to the above indigenous species, some 18 freshwater species were introduced into Vietnam for aquaculture, of which some are carps. They are silver carp, bighead carp, grass carp, rohu, mrigal, catla and common carp. They account for over 90% of aquaculture production.

Based on morphology and coloration, eight varieties of common carp have been identified. Characterization of Chinese carps and Vietnamese silver carp has been carried out.

4. STATUS OF CARP GENETICS RESEARCH AND BREEDING PRACTICES

As a first step in developing work plans for genetic improvement of carps in each of the participating countries, past and ongoing genetics research and breeding programs were reviewed, research to be carried out under the project was discussed and work plans for the next three years, for each of the participating countries, were finalized. The status of carp genetics research in each of the countries and the research planned, is detailed below. The detailed country reports are in Annex 2.

4.1 Bangladesh

Meiotic gynogens of rohu and mrigal were produced and females were the homogametic species. Studies conducted for sex reversal of mrigal were not successful.

Variable response was observed for heterosis for growth of individual families of reciprocal rohu-mrigal hybrids.

Three strains from Bangladesh, Indonesia and Thailand are being used for genetic improvement of silver barb *(P. gonionotus)*, through selective breeding and line crossing techniques. The three strains were crossed in all combinations. Preliminary results indicated little heterosis for growth rate.

Studies are in progress for producing monosex female silver barb through gynogenesis and sex reversal and for producing gynogenetic lines of catla and clones of rohu.

Techniques were developed for breeding mahseer *(Tor putitora)* and barb *(Puntius sarana)*.

4.2 China

Four generations of selection increased growth rate in blunt snout bream by 19%. Two generations of inbreeding decreased growth by 16%. Commercial stocks may be exhibiting decreased growth, poor body conformation and early maturity. Selection is being evaluated to counteract this degradation of the commercial stocks.

Intraspecific crossbreeding has been successful for improving growth, and feed conversion in common carp and crossbreeds are often used by farmers. Gynogenesis has been accomplished in several species and the allogynogenetic crucian carp, *Carassius auratus,* produced by mating with common carp, grows well and is liked by the farmers. Several polyploids have been produced, and the triploid common carp -crucian carp has commercial value. Attempts to produce valuable mutants by irradiation and chemical means were unsuccessful. Utilization of combined breeding programs, family selection, inter-family mating and gynogenesis have been successful and widely used. Nuclear transplantation has been accomplished, but the performance of these fish has not been adequately evaluated. Gene transfer research has been initiated in carps, and the first transgenic fish were produced in China.

4.3 India

Several hybrids including interspecific, intergeneric, F_2, three way and back crosses have been produced. None of these showed better growth than the best parent, however, some express higher flesh content. Some hybrids were sterile, which will be useful for stocking in certain environments.

Cytogenetic studies were undertaken in about 250 species. Techniques have been established to produce gynogenetic and polyploid carps.

Selective breeding for increased body weight has been initiated in catla and rohu. One generation of selection in rohu improved growth on average by 13%.

Experiments for production of transgenic carps are in progress. Studies are in progress for developing methods for identification of species specific genetic markers.

4.4 Indonesia

The selection program undertaken for common carp focused on color and body depth. Based on morphology and behavior, nine Indonesian strains were developed. Color inheritance of these common carp were determined. Various color morphs differed for traits, such as growth, survival, disease resistance and predator avoidance.

Interspecific hybridization of carp has given mixed results, some hybrids expressing heterosis and others none. Gynogenetic common carp have been produced and characterized.

4.5 Thailand

Sex determining mechanism in silver barb *(P. gonionotus)* was studied. The female is the homogametic and faster growing sex in silver barb. Production of monosex females has been accomplished and their utilization in aquaculture improved production.

Diploid and triploid silver barbs were produced and no significant difference in growth was observed at 10 months of age. Potential use of microsatellites for broodstock improvement in aquaculture, was studied.

Growth performance in common carp strains evaluated varied. Intraspecific crossbreeding often improved growth rate. However, genotype-environmental interactions were observed when fish were compared using different feeding strategies. Intraspecific backcrossing was effective in altering body shape.

Heritability for growth rate in rohu and bighead carps was studied and was observed to be low.

4.6 Vietnam

Significant differences were observed for the growth and morphology of different strains of common carp. Performance of bighead carp and silver carp hybrids was intermediate compared to their parents. Intraspecific crossbreeds of common carp exhibited heterosis for growth, survival and appearance. However, strains may have been introgressed with a corresponding deterioration in performance. Five generations of selection for increased body weight in common carp has improved body weight by 33%.

Karyotypes of silver barb, *Puntius altus,* and catla have been examined. Triploid common carp and gynogenetic silver barb have been produced and are being evaluated.

5. STATUS OF CARP FARMING INDUSTRY

This section provides the summaries of the papers presented and discussed during the third technical session of the Planning Workshop. The detailed country reports are in Annex 3.

5.1 Bangladesh

Bangladesh is basically an agrarian economy. Fisheries, as a component of agriculture, plays an important role in improving nutrition and in generating employment and foreign exchange earnings for the country. It contributes about 80% of the national animal protein intake, 5% of the GDP and more than 12% of the export earnings. Total fish production comes from 4.05 million ha of inland open waters, 0.29 million ha of inland closed waters and 0.166 million km^2 of marine waters. About 77% (capture in open waters, 50%; culture in closed waters, 27%) and 23% of the country's total fish production of 1.17 million mt in 1995 came from inland and marine sectors, respectively. In recent years, however, growth in fisheries production is coming mainly from aquaculture. Though aquaculture is growing very fast, the average yield is comparatively lower than most of the other countries in Asia (ponds, 1.8 t/ha; baors, 0.4 t/ha; shrimp farms, 0.3 t/ha).

Fish production from ponds is the most important component of the aquaculture sector. There are 1.3 million ponds with a total area of 147,000 ha in Bangladesh. Among its 19 districts, Comilla, Chittagong, Rajshahi, Noakhali, Mymensingh, Dinajpur and Jessore are the leading districts in fish pond production, mainly carp species. Currently, carps account for about 77% of all fish species reared in ponds. Rohu, catla and mrigal are the most preferred aquaculture species in the country. Their popularity can be attributed to high consumers' acceptance (better taste), better market price and social prestige.

The values and the culture systems, however, have undergone a major change with the efforts of the Fisheries Research Institute, ICLARM and NGOs, to promote polyculture for maximum utilization of pond productivity. Polyculture is now widely accepted in Bangladesh with rohu, catla, mrigal, silver carp, mirror carp, grass carp, kalbasu and silver barb as the widely used fish species. Tilapia is of recent interest to fish farmers though it requires minimum cost and care. Fish farmers' attitude on input use has also undergone a major change. It is now relatively easy to convince them to use the necessary farm inputs (e.g., cattle manure, urea and compost) as compared to few years back. Also, they are becoming more receptive to the production technologies recommended by government institutions and NGOs working for the development of aquaculture.

Fish farming is becoming a very profitable endeavor but also a very risky one. The benefit-cost ratio (BCR) of fishpond operation is ranging from 1.56-8.58. These wide variations can be attributed to differences in management practices, sizes of ponds, intensity of input use, factor and market prices.

In Bangladesh, the following were constraining the growth and development of carp farming which might be applicable to aquaculture in general: 1) social (fear of theft and poisoning, lack of proper cooperation of concerned agencies, interference of village leaders, joint ownership/operation of ponds, lack of quality seed in adequate quantity, problems created by vested interest villagers in getting lease, cheating by the fry/fingerling suppliers in specifying type of species); 2) economic (high prices of feed and other inputs, lack of capital and credit, lack of proper markets and marketing facilities, low harvest prices of fish); 3) technical (diseases and parasites, insufficient water in dry season, high mortality of fingerlings, difficulty to maintain water quality, faulty pond design and sizes, limited knowledge of the culturists); and 4) infrastructural (inadequate and poor roads and highways, inadequate transport and storage facilities, absence of central pooling (landing) spots).

Rohu, catla, mrigal are receiving relatively higher farm gate prices than other carp species. These carp species had prices higher than those of other carp species in 1994 (rohu, Tk[1] 50/kg; catla, Tk 47/kg; mrigal, Tk 45/kg; kalibaso, Tk 45/kg; common carp; Tk 41/kg; mirror carp, Tk 40/kg; grass carp, Tk 37/kg; and silver carp, Tk 34/kg). At retail market, rohu is also priced higher than the other fish species. Prices of all fish vary widely due to differences in the size of fish and spatial differences in marketing and transport costs.

According to the Department of Fisheries, the supply of fish for domestic consumption has stabilized at about 7.5 kg/capita/annum since the late 1970s. But

[1] 1US$ = Tk40.00

the data from Bangladesh Bureau of Statistics (BBS) Expenditure Survey indicated that annual per capita fish intake increased from 9.84 kg in 1973/74 to 12.59 kg in 1991/92. The annual fish per capita consumption is higher in urban (17.45 kg) than in rural areas (11.86 kg) and is sensitive to changes in income i.e., as income increases, fish consumption increases. This responsiveness of fish consumption to changes in incomes is reflected in the highly elastic income elasticity of demand for fish ranging from 0.96-1.03.

There is no study on demand for specific species like carps. Fish demand is projected to increase to 1.8 million mt in year 2009-10. The gap between the supply and demand is projected to be 33% for the slow growth scenario and 13% for the moderate growth scenario (World Bank, 1991).

Despite the involvement of several government, non-government, and international organizations in carp culture research, socioeconomic studies have not received attention. As such some of the research needs for the development of aquaculture, in general, and carp farming industry, in particular, may include: 1) assessment of production technologies prior to its promotion and diffusion; 2) determination of optimum input application, pond size, depth of pond, etc. under different environments, culture systems and socioeconomic status of fish farmers; and 3) market studies, consumption patterns, price and demand analysis.

5.2 China

China has the longest history of freshwater aquaculture in the world that dates back to 5 B.C.. Strong government policy to promote fisheries development to meet the increasing demand for fish and other aquatic products has resulted in rapid development not only of the freshwater aquaculture but also of the fisheries sector as a whole. The fisheries industry has been growing tremendously since the end of 1970s. By 1996, the national production of aquatic products reached over 28 million tons, a way far ahead of other countries in the world.

Freshwater fish production contributes about 43% of the total fish production. This can be attributed to the rapid development of freshwater fish culture. In 1995, total freshwater fish production reached 10.78 million tons, of which bulk of production came from aquaculture (87 %) than from capture fisheries (13 %).

There are more than 800 different freshwater fish species in the country. Carp species dominate freshwater capture fisheries production contributing about 80-90% of the total fish catch. Despite the introduction of several exotic freshwater species in different aquaculture systems, carp species are widely cultured. Eight of the 10 major carp species being cultured, are of national economic importance, namely: black carp (*Mylopharyngodon piceus*), grass carp (*Ctenopharyngodon idella*), common carp (*Cyprinus carpio*), silver carp (*Hypophthalmichthys molitrix*), bighead (*Aristichthys nobilis*), crucian carp (*Carassius auratus*), and Chinese bream (*Megalobrama amblycephala* and *Parabramis pekinesis*). Production of these 8 species reached nearly 9 million tons in 1995 and together accounted for about 95 % of the total freshwater aquaculture production.

The aquaculture industry is in various stages of development in China. The geographic distribution of different carp species is also very uneven. These variations can be attributed to differences in the levels of aquaculture development, climatic conditions and socio-cultural traditions. In general, carp production is much more concentrated in southern and eastern parts of China, especially the middle and lower reaches of the four major river systems: Yangtse River, Pearl River, Yellow River and Heilong River. Among the major cultured species, silver carp, bighead carp, common carp and crucian carp are relatively evenly distributed all around the country. Grass carp and Chinese bream are mainly raised in the south-eastern part of China. Whereas, black carp is mainly cultured in the middle and lower reaches of Yangtse River and Pearl River.

With wide variation in the country's natural environments and socioeconomic backgrounds, various culture systems for carps have evolved. Currently, polyculture is a dominant system for culturing carps. However, carp monoculture is becoming popular for very intensive culture in cages, ponds and running water systems. Species composition of different polyculture systems is rather complicated. Stocking formula of carp varies with regions, culture intensity, farming practices and many other factors. Even at the same farm, there can be different stocking formula usually subject to changes in demands.

There are basically four types of carp farms: state owned, collective, family-based private and private commercial farm. Farm size is very much related to the ownership and culture system. Generally, state owned and collective farms are larger in size than private farms. In recent years, several private commercial farms are joining the industry as the market-oriented economy is developing in China. These large private carp commercial farms are usually concentrated in the special economic trade zones resulting in geographic variation in farm size (pond culture, 1-50 ha; cage culture, 10-2,000 m^2, lake/reservoir, 50-2,000 ha).

Income sources of carp farmers greatly depend on their geographical location and on the economic opportunities in the area. In more developed area, income of fish farmers consist of fish production, small industry (such as processing and culture related), and commercial activities, such as restaurant and tourism etc. But in less developed rural areas, income of carp farmers usually comes from fish production and agriculture and animal husbandry. Currently, it is very hard to have precise income data of fish farmers especially carp farmers. In general, income level of fish farmers is higher than ordinary farmers. In some areas, it is even higher than the income of factory workers. In 1995, the average annual per capita income of fish farmers and fishermen was 3,352 yuan[2] and 6,642 yuan, respectively. While, average annual per capita income of agricultural population was only 1,580 yuan for the same year.

Inputs for carp culture are entirely dependent on culture system and production level. Generally, production cost of intensive culture systems is higher than with the extensive systems and increases along with production levels. Feed, seed and labor are the major inputs in carp farming. On the other hand, there have

[2] 1US$ = 7.8 yuan

been various experiments to determine maximum carp yield attainable for different culture systems. The followings are some of the "best" or highest yields: 1) pond culture: 38 t/ha; 2) cage culture: 2,973 t/ha; 3) pen culture: 75 t/ha; and 4) lake/reservoir: 2t/ha. At the farm-level, yield is generally higher in the areas with long history (traditional practice) of carp culture. However, it is quite difficult to separate the yield of different carp species in different culture systems since polyculture is a dominant system.

Profitability of carp farming is very much determined by culture system and culture intensity in China. Profit per unit of water surface area is higher in intensive culture system (pond culture, US $1,009/ha/yr) than in semi-intensive (pond culture, US $331/ha/yr) and extensive (pond culture, US $524/ha/yr). Also, higher profit can be obtained in cage and pen fish culture (US $2258-6244/ha/yr) than pond fish culture (US $331-1009/ha/yr).

Currently, carp culture has developed to a very high level in terms of production per unit area. Further increases in yields are constrained by many factors such as: (1) biotic constraints (disease problem); (2) environmental constraints (deterioration of natural environment, changes in water temperature); and (3) socioeconomic constraints (high input requirements, changes in fish species preference as income improves).

As fish prices were strictly controlled by the government before the 1980s, there was no seasonal fluctuation and no spatial fish price differentials at that time. Recently, due to economic reforms that led to the development of market-oriented economy, prices of fish have exhibited some instabilities. Prices now depend on the balance between the demand and supply of fish products and consumers' preference. Currently, prices of carp species range from US $0.60/kg-2.5/kg and their prices are much higher in more developed areas of the country.

Generally, carp species are not highly priced fish and affordable among different income groups. Due to differences in meat quality, market prices among carp species vary. Better quality species like black carp, crucian carp and Chinese bream with higher market prices are only consumed by higher income groups, while species like silver carp and bighead carp with lower market value are mostly consumed by lower income groups. Consumption of different species by different income groups is also determined by local customs of the people. For instance, common carp is considered as a high quality fish in northern and south-western part of China, but it is not so preferred by the people in other areas. For crucian carp, it is almost the opposite.

Prices do have significant impact on the demand for carps. The magnitude in changes of demand due to changes in prices, however, is not available yet for specific carp species. Changes in consumers' income is also affecting the demand for carps i.e., demand increases as income increases and vice-versa. This is particularly observed in areas with less developed economy and aquaculture industry. But this situation does not hold in economically developed areas as an increase in income may shift demand to better quality fish species not necessarily carps. If they will consider carp, it will be for high quality carp species.

Though China is world's highest producer of fisheries products, its annual average per capita fish consumption (14 kg) is only slightly higher than the world's average (13 kg). This is partly due to its large population. Nevertheless, as the living standard of the people improves and with the increasing perception that fish is a much better animal protein food, it is expected that fish demand including that of carp will also increase.

In the past, most of the fisheries economic studies were focused on bio-economics and technical aspects of different culture systems in specific regions of the country. There were only few studies on the socioeconomic aspects of carp culture. Hence, the following aspects should be the major focal points for future socioeconomic research: 1) factors affecting the development of carp industry and its socioeconomic impact; 2) environmental-economic studies on carp culture; 3) comparative economic study of carp culture systems; 4) socioeconomics of carp genetic improvement and bio-diversity conservation.

5.3 India

India is endowed with natural resources suitable for aquaculture. It has 8,085 km of coastline, 164,000 km of rivers and canals, 1.97 million ha of reservoirs, 2.2 million ha of ponds and tanks; 1.3 million ha of beels, oxbow lakes and swamps, and 1.4 million ha of brackishwater area. Traditionally, aquaculture has been practised in freshwater and coastal saline waters characterized by low-inputs and low-production systems. However, aquaculture has been slowly but steadily transforming itself into a business activity during the last decade. Aquaculture production increased almost threefold from 511,500 t in 1984 to 1,438,900 t in 1993.

Carp is dominating the freshwater aquaculture in ponds, cages, pens and recirculating systems and inland fisheries production in India. Carp production constituted about 44 % of the total inland fishery production of 5.14 million tons in 1996. In aquaculture, however, only carp pond culture has reached commercial level. The rests are under experimentation or rather being operated on a "small" or limited scale. The national productivity of carp culture in ponds has increased from 900 kg/ha/yr in 1984-85 to 2,130 kg/ha/yr in 1994-95. Freshwater carp culture is widespread in West Bengal, Madhya Pradesh, Orissa and Bihar. Area concentration of carp culture is greatest in Kolleru Lake. Among its different states, Punjab (4,100 kg/ha/yr), Haryana (3,660 kg/ha/yr) and Andhra Pradesh (3,500 kg/ha/yr) have the highest average productivity, while Meghalaya (700 kg/ha/yr) has the lowest. Consumers' demand is a major factor influencing the choice of species to culture in the country.

The composite carp culture technology and induced breeding of carps are the two pillars for the development of carp industry in India. The composite carp culture technology was developed at the Pond Culture Division of the Central Inland Fisheries Institute, Cuttack during the 70s. The standard management practices include preparation of pond, eradication of aquatic weeds, control of predatory and weed fishes, manuring and fertilization, choice of stocking density and size, optimum ratio of different combination of fish species and fish health (Aravindakshan 1996). While, the induced breeding technology was developed as an alternative to collection of carp seeds from the wild. Through induced breeding, quality carp seeds are now available throughout the year in most parts of India.

The technology for composite carp culture can be categorized as extensive, semi-intensive or intensive in terms of input usage. As expected, intensive composite carp culture is the most profitable system. While the net farm income per hectare was only about Rs 76,100 for extensive and Rs 90,000 for semi-intensive system, it was about Rs 127,000[3] for the intensive system. Though the cost of production per kg of fish was higher in the intensive system (Rs 19.40) compared to the extensive (Rs 11) and semi-intensive (Rs 18.70), intensification especially those with limited farm area provides an opportunity for fish farmers to increase their farm income.

Operating carp hatchery is more profitable than engaging in its grow-out operation. For a hectare of carp hatchery following a single time induced breeding system, it is possible to produce 60 million of spawns for a gross return of Rs 330,000 and a net farm income of Rs 106,000. With the switch to multiple induced breeding system, 200 million spawns can be produced for a gross return of Rs 1,118,000 and net farm income of Rs 753,000.

The high profitability of carp farming either of grow-out or hatchery operation has led to the shift in the farming systems from food crops towards aquaculture in India. These changes are very prominent in some states like Andhra Pradesh, Tamil Nadu and Punjab. In these states paddy and wheat fields are being converted into carp culture ponds. For as long as profit or income from carp farming is higher than crop farming, there would be more conversion of crop lands into carp culture ponds. Currently, this has been the major source of growth of the carp industry in India.

However, the growth of carp production through land conversion may not be that substantial as the carp industry is faced with the following problems or constraints affecting its growth and development: 1) floods; 2) siltation; 3) sewage pollution; 4) pesticide pollution; 5) aquatic weeds; 6) industrial pollution; 7) red tides/plankton blooms; and 8) eutrophication.

In India, there is lack of information with regard to socio-economic and policy aspects in aquaculture. Thus, some of the research needs for the development of aquaculture, in general, and carp farming industry, in particular, may include the following: impact assessment of technologies, constraint analysis, priority setting, demand analysis and market studies.

5.4 Indonesia

Indonesia is producing two major species of carps i.e., common carp (*Cyprinus carpio*) and Nilem carp (*Osteochilus hasselti*), and Java barb (*Puntius javanicus*). It is the world's third largest producer of common carp after China and USSR. Common carp comprised about 92% (146,000 mt) of the country's total carp

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[3] 1US$ = Rs 36.00

production in 1994. Most or 96% of the common carp production comes from aquaculture (paddy fields: 42%; fish ponds: 38%; and cages: 16%) and only 4% from capture fishery. Common carp production from aquaculture registered a moderately high annual growth rate of 12% from 1985-1994. Due to its low production base, cage culture production posted a higher annual growth rate (82%) than pond culture (10%) and paddy field (8%). Common carp is cultured throughout Indonesia. But, bulk or 70% of the country's total common carp production from aquaculture comes from the province of West Java.

Carp fish farmers are either engaged in hatchery or grow-out operations or in combinations following monoculture or polyculture systems. On the average, fry production per kg breeder of hatchery farms in the country ranges from 50,000 to 80,000. Grow-out operators are raising carps in rice-fish fields, floating net cages and fishponds. Carp culture in ponds is very popular among grow-out operators. About 74.7% of them are culturing carps in ponds, 23.7% in paddy field and 1.6% in cages. Grow-out operators are operating a net water surface area ranging from 0.02 to 0.26 ha, 0.75 -158.30 m2 and 0.20-0.56 ha, in case of ponds, cages and paddy field, respectively.

Carp farming is just one of the main sources of household income of carp farmers. Their other major sources of income are agriculture, trading and employment (government sector). In the case of carp farmers in Saguling reservoir, their income from fishery (including carp farming), agriculture, trading and employment comprised about 39, 15, 17 and 30% of their total household income of Rp 4,206,136 in 1994 (US$ 1=Rp 2161). In general, income from carp farming is higher than agriculture.

Carps are cultured in intensive, semi-intensive or extensive systems. Intensive carp culture in continuous flow (running water) ponds and floating net cages is characterized by the higher inputs use and capital. In semi-intensive carp cage culture, feeds come mainly from the organic materials carried downstream in which supplementary feeding with kitchen wastes, agricultural by-products and fresh leaves are supplied occasionally, while carp farming in rice fields and standing water (ponds) depend mainly on natural food as a source of nutrients. Fry and feed costs constitute about 92-93% of the total production cost in a typical carp cage culture in Indonesia. Total production cost ranges from Rp 20.53 - 31.97 million with net farm income ranging from Rp 3.35 -5.47 million per annum (US$1 = Rp. 1843) for operating a cage with an area of 490 m^3 in 1990.

At the national level, fish farmers' lack of skills to implement the required cultural practices and under utilization of the rich water resources are the major problems constraining the development of freshwater aquaculture. Utilization rate of water bodies is only about 30 %, and only 3 % is intensively utilized for fish farming. At the farm level, lack of operating fund, high cost of feed, low price of fish and poor fish quality are the major problems faced by (grow-out) carp farmers. Carp hatchery operators are having problem of high fish mortality in ponds during the first 21-30 days (Nursery I cycle) after hatching. "Small" fish farmers considered lack of fund for purchasing seeds, feed and for other operational expenses as their major problems. In addition, most small farmers were obliged to purchase feed through credit from the middlemen at high interest rate. Local middlemen are usually big farmers who are also feed dealers and fish brokers.

Carp farms, especially those with high degree of dependence from irrigation to supply their water requirement, are adversely affected by the frequent fluctuation in the volume and quality of water supply during the year. In some farms, parasites and diseases problems have been encountered. However, these have not yet been considered as serious problem among fish farmers. From 1976-1986, culture of common carp in running water was a good business due to higher prices. But, with the introduction of carp culture in floating net cages, there has been drastic reduction in the prices of carps in Indonesia due to production glut. Even in West Java, which generally has a good market price for common carp, is affected during periods of bumper production.

Prices of inputs have been increasing substantially in Indonesia. For fry/fingerlings, it is not only the increasing price but also the lack of good quality and instability of its supply that are causing economic losses to carp farmers in the country. Often fry are not available at the right time causing substantial set back in production cycle. The increasing prices for fry/fingerlings can be attributed to high demand from floating net cages in man-made lakes or reservoirs. The price of feed is also increasing from year to year. On the other hand, the increase in the price of fish usually is not proportional with the increase in the price of feed. Also when a farmer in particular location is successful, others follow. These new farmers would usually construct their farms further upstream from the old farm. Consequently, polluting the ponds downstream resulting in slow growth and high feed conversion rates. Water use conflicts is another major problem between those operating running water ponds and floating net cage systems.

In Indonesia, the demand for carp is determined mainly by its market price. The price of carp depends on the fry price, fry supply, fish size, transportation, ethnic preference, and season. In July 1992, the market price of carp reached even Rp 2500-3000/kg (US$1 = Rp 2030) at Cissat fish market. Normally, the price of carp fluctuates around Rp 2000/kg with prices at its highest in October and lowest in March.

Fish consumption is increasing in Indonesia. Per capita consumption of fish grew annually at 1.9% from 10 kg/annum in 1968 to 16 kg/annum in 1993. The increasing demand for fish can be attributed to the general improvement of the country's economy. This can be expected as the income elasticity of fish demand in Indonesia of 1.06 can be considered elastic, i.e., an increase in income will induce more demand for fish proportionately. In addition, fish demand or consumption of fish and carp in particular can be expected to increase in Indonesia due to consumers' high preference for fish as their main source of animal protein as they are becoming more health conscious.

In Indonesia, most of the socio-economic research dealt with the benefit-cost analysis of the production and marketing of grow-out and hatchery operators under different carp culture systems. Hence, the following research needs have to be addressed :

1. Productivity, benefit-cost analysis, and level of technology used in carp fish culture in terms of species, size of farm, culture system, and area.

2. Estimation of demand function of carp and consumer behavior in terms of species, group of people, location and season.

3. Identification of potential market (domestic and international)

4. Improvement in fish farmers bargaining position, accessibility to capital or financial sources, technology, market, and information.

5. Substitution of expensive feed ingredients with locally available cheap materials to reduce the feed cost. Also, determination of optimum feeding rate, including frequency and method, and stocking densities in relation to the quantity and quality of water for maximum utilization of water resources for carp culture.

5.5 Thailand

Freshwater fish in Thailand are an important source of animal protein and are highly affordable to consumers. Tilapia, carp and catfish are some of the freshwater species of economic importance. Among these species, carp is the popularly farmed species contributing about 18 and 14 % to total quantity and value of freshwater fishery production.

In Thailand, capture fishery accounts for the bulk or 57 % of carp production, while the rest or 43% production comes from aquaculture. Nevertheless, carp aquaculture production is posting robust growth rates than the capture fishery. In fact, the capture fishery carp production is already declining. With robust growth rate and government intensifying its support for the development of freshwater aquaculture, carp aquaculture production is expected to post substantial growth and may eventually become the major source of carp production. At the species level, Thai silver barb (*Puntius gonionotus*) and common carp are the two major species cultured and caught in the inland freshwaters. Thai silver barb is dominating both the aquaculture and inland capture fishery production. This is expected as it has long culture history, being a native carp species, than common carp, an exotic species.

Although carp is cultured in six regions, its production is concentrated in Northern Thailand which accounts for about 35 % of aquaculture production. Carps are mainly cultured in ponds and its production amounts to about 92 % of carp aquaculture production. Among the existing culture systems i.e., pond, paddy field, ditch and cage, the latter is only recently introduced in Thailand. Carp cage culture is mainly found in Northern and Northeastern and Central-Plain regions of Thailand. Though bulk of carp production is coming from Northern Thailand, high concentration of carp farms and areas for carp farming are found in Northeastern Thailand. This region accounts for 57 % and 60 % of the total number of farms (67,012 farms) and total area (16,177 ha) for carp farming in Thailand. This indicates that there are differences in regional productivity of carp farming in

Thailand. Carps are widely raised in fishponds than in paddy fields, ditches and cages. Fishponds constituted about 91 % of the total numbers of carp farms. Again, most of the fishponds are concentrated in Northeastern Thailand.

Carp farmers are incurring a total production cost of Baht[4] 21,022 per farm or Baht 8,984 per ha. About 73% of this total cost is considered as cash costs and 27% as non-cash costs. As feed cost accounts for about 35% of the total cost, this implies that carp farming is a commercialized aquaculture activity in Thailand. With an average production of 2,398 kg/farm or 1,025 kg/ha, carp farmers are earning a gross income of Baht 36,354/farm or Baht 6,552/ha and a net income of Baht 15,332/farm or 6,552/ha. With a farmgate price (Baht 15.16/kg) almost twice the cost to produce a kilogram of fish (Baht 8.77), carp farming can be considered a highly profitable aquaculture activity in the country.

Currently, farm prices of carps range from Baht 19-27/kg. Due to consumers preference for common carp, it is usually priced higher than Thai silver barb. There has been considerable fluctuation in the monthly farm prices of carps in Thailand. Farm price of Thai silver barb is at its lowest level usually in October and at its highest in December, while price of common carp is at its lowest in November-December and highest in April. The lowest and highest levels of farm prices of Thai silver barb and common carp are directly associated with their peak and lean production months.

The Office of Agriculture Economics has estimated that the demand for freshwater fish species will reach 290,492 tons in 2001 or a yearly increase of 2,919 tons from the 1992 level of 224,437 tons. This increase demand is expected to be met mainly by freshwater aquaculture production as capture fisheries production has been declining in recent years. As one of the major freshwater aquaculture species, carp production is expected to increase parallel to increase in demand of freshwater species in Thailand.

No specific socioeconomic research on carp culture has been undertaken in Thailand. But, the Office of Agriculture Economics has conducted several research studies on the production and marketing of freshwater species in Thailand. Specifically, these studies focused on: 1) problems of production and marketing of freshwater fish species; 2) socioeconomics of freshwater aquaculture; 3) costs and returns of freshwater aquaculture; and 4) production and resource-use efficiency of freshwater aquaculture. Hence, to sustain and develop further the carp industry, the following research needs to be undertaken: 1) feasibility study of developing a new species of carp; and 2) comparative economic study of new carp species and local species.

5.6 Vietnam

As a rice-fish society, the Vietnamese have a proverb: "Rice and fish like mother and child". In Vietnam, fish are consumed by most people and fish are a very important animal protein source and food security for about 90% of the

[4] 1US$ = Baht 26.00

population in rural areas. Fish consumption was around 15 kg/caput/yr sharing nearly 35% to total animal protein intake. Aquaculture is one of its major sources of fish products. It contributed about 0.40 million tons out of the total fish production of 1.37 million tons in 1996. Geographically, most or 42 % of the marine fish production comes from South-east Vietnam. While, South-west, Central and Gulf of Tokin accounts for only 26, 20 and 12 % of the marine fish production, respectively. In aquaculture, the Mekong River Delta is playing an important role in aquaculture production, accounting for 67 % of total aquaculture production.

Traditional carp culture has long been practiced in Vietnam. It was first practiced by the rice farmers to culture fish in ricefields and village ponds to supplement their nutritional requirement. The main cultured fish species are common carp and other indigenous fish. In the 1960's, with the introduction of Chinese carps (silver carp, big head carp, grass carp) together with the success in induced breeding of these species, fresh water fish culture entered into a new era. But, carp farming became only an important component of the rural economy of Vietnam in the early 1980s, with the introduction of a major group of Indian carps such as rohu (*Labeo rohita*) , mrigal (*Cirrinus mrigala*) and catla (*Catla catla*).

In Vietnam, carps are mainly cultured in polyculture system. The main cultured species are: 1) Chinese carps (silver carp, grass carp and big head carp); 2) Indian carps (rohu, mrigal); and 3) local fish species (catfish, common carp). The culture system is primarily semi-intensive culture using only a minimum amount of fertilizers, rice bran and other agricultural on-farm/off-farm by- products. In addition to polyculture system, an integrated farming system known as a VAC system is practiced popularly in Red River Delta. In the system, V stands for garden, A stands for fish pond and C stands for livestock. This system promotes by-products recycling within the farm and has been accepted by the farmers. In VAC system, fish pond shares the main part of output and income of the farmers.

On the average, carp farm size ranges from 0.5 to 1 ha in Vietnam. The size of pond varies from 200 to 1500 m^2. Normally, each fish farming household owns 1 or 2 ponds with water availability throughout the year. Pond water depth ranges from 1.0 to 1.6 m, considered suitable for carp culture. The culture period often starts at the beginning of rainy season (May-June) and ends in the dry season (December-January). Ponds are often completely drained to facilitate harvesting of fish. After harvesting, the pond bottom is dried for a few days and is limed, manured and filled with water in preparation for new grow-out season. Water being supplied to the pond are sourced either from irrigation canal, rainfall or reservoir.

Carp farmers' household income comes primarily from aquaculture, livestock, crop cultivation and other on-farm and off-farm activities. It is estimated that carp farmers have 2 to 3 times higher income than the average rice farmers. On the average, a fish farmer can earn a gross income of about Dong[5] 10 million per ha of fishpond. The main inputs in carp farming are labor cost, fingerlings, fertilizers and feeds. Members of the household supply most of labor requirement in carp farming. There is abundant supply of labor as a household is composed of 5 to 6

[5] 1US$ = VND11,000

persons. Slowly, women are being involved in carp farming. Female members of the household provide the necessary labor in carp farming if required. Overall, the cost of fingerlings has the largest share in total production cost. The rest are costs of manure and rice bran used in aquaculture. On average, about VND 20 million investment is needed to set up a hectare of fish pond.

The main problems faced by fish farmers are inadequate credit, flooding, fish disease, poor extension services, poor quality seeds, poor water quality and high seed prices. Recently, a government bank catering for the financial needs of the agriculture sector has started providing loans to farmers with low interest rates. However, due to complicated borrowing procedures and the requirement of collateral, most of the poor farmers could not avail of this cheap credit. The difficulty to control the damage caused by fish diseases such as red spot disease has been the source of heavy economic loss in fish culture. In addition, lack of quality fingerlings is also a major constraint. Due to competition in the use of feeds (including fish meal, rice bran, soybean and other local ingredients) between carp culture and livestock farming, there is acute shortage of feeds for fish culture. The use of pesticides for agricultural crops affects carp culture in ricefields and village ponds and causing high fish mortality. Poor aquaculture extension services is also a factor constraining aquaculture development in Vietnam.

Despite the recent entry by some commercial grow-out fish farms with higher intensification levels of inputs to achieve higher productivity, the major part of freshwater fish production still comes from small-scale fish farms. As there was no substantial production, freshwater fish trading is also dominated by small-scale traders. In Vietnam, there are two kinds of fish traders: 1) producer- trader, selling directly their produce in the local markets; 2) the "real" traders, dealing mainly with buying and selling of fish commodities.

Normally, the fish are often sold in local market or near the fish production area. The distance of the market and the source ranges from 5 to 15 km. Majority of fish traders transport the fish from their sources to the market using bicycle and motorcycle. Normally, it takes about 20-60 minutes to transport fish from farm sites to market. For that reason, the marketing cost is low and the consumer can buy very fresh fish at a cheaper price. In the case of the fish producers that directly take their produce to the market, they can get good price and earn more income. As there is no so much difference in the selling prices of fish between peak and lean season, they are earning more income during the peak season. The fish being traded in the market have sizes ranging from 2-6 fish/kg. Most rural consumers show preference for smaller fish. The price of fish varies with fish species, distance from source of fish and market, and regions.

On average, a household consumes about 60-80 kg of fish per year, accounting for 12 to 18 % of total food expenses. However, fish species consumption differs for different income groups. High, middle and low income classes consume common carp, Indian carps and Chinese carps, respectively, as major species. Most of these carp species have negative and highly elastic own-price elasticities indicating that when their prices increase, consumers will consume less. With positive cross price elasticity, these fish groups are substitutable. Also, with positive expenditure elasticity in general, it is expected that fish demand will increase as income increases. For specific fish groupings, the expenditure elasticity is elastic for Indian carps and other fish groups and inelastic for tilapia and Chinese carps. This implies that consumers prefer spending their income in consumption of Indian carp (rohu and mrigal) and other fish groups such as grass carp, pangasius and silver barb.

Currently, the Research Institute for Aquaculture No. 1 (RIA No. 1) is taking initiative in improving the productivity of freshwater species in Vietnam particularly carp and tilapia. Furthermore, there is widespread recognition that with the growing demand for fish, it is necessary to improve carp seed quality through selective breeding programmes, to promote sustainable yields of carp in semi-intensive culture system and to undertake constraint analysis for increasing productivity of carp farming.

6. METHODOLOGY

The methodology for each component of the Project developed in consultation with the various research partners is presented in this section.

6.1 Characterization of carp genetic resources

Documentation of carp genetic resources will be undertaken under this component. It would require systematic documentation of carp genetic resources and their evaluation and utilization in the six-participating countries: Bangladesh, China, India, Indonesia, Thailand, and Vietnam. As a collaborative effort, each country will prioritize the species for which they would submit information since the information to be collected may be unmanageable if information for all cyprinids is included. Information for the documentation will come from all available published sources.

The following information will be collected and compiled as these are critical for the proper documentation of carp resources: 1) biology of the species, providing brief biological description containing general information such as taxonomic status of the species, its general characteristics and its distribution; 2) status of the genetic evaluation, genetic improvement and utilization of different genotypes of carps, emphasizing on the description of previous experiments involving aquaculture production traits of various genotypes; 3) utilization of genetic resources, providing examples of genetic breeding programs at hatcheries and farms and examining population sizes and broodstock sizes; 4) documentation of genetic resources in carps, including molecular, quantitative and qualitative resources; 5) genetic characterization of populations or genotypic groups, examining isozymes, isoelectric focusing, immunological markers, blood types and molecular markers; and 6) cytogenetics of carps, including karyotypes, chromosome numbers, NORs, FISH, arm numbers and genotoxic data. All sources of data will be properly referenced.

A detailed description of methodology to be followed is presented in Annex 4.

6.2 Socioeconomic and priority setting research for carps

Prioritization of carp genetics research will be undertaken in the six-participating member-countries. To accomplish this objective, the activities identified were: 1) assessment of how, and to what extent existing carp species/strains are valued by different groups of the society (farmers, consumers, landless laborers, etc.); 2) analysis of present and future importance of various farming systems including problems and opportunities for increasing production in these environments; 3) estimation of future demand for various carp species by income groups; and 4) prioritization of carp genetics research. It must be noted that at the beginning of the Project, ICLARM's economist will develop appropriate methodology for carp genetics research prioritization. Subsequently, trainings and seminars will be conducted in different participating countries.

In Activities 1 and 2, baseline surveys of existing and potential carp producers and consumers will be conducted in multiple sites within each country to represent diverse agroclimatic and socio-economic environments. Data will be analyzed using descriptive and statistical (econometric) approaches. In Activity 3, the demand function for various carp species will be estimated mainly based on "household expenditure survey" data. In case these data are not available, special consumer surveys will be conducted. Activity 4 requires information on both the demand and supply sides of carp research, and the analysis will be done at 3 levels : species, farming systems and traits. Constraint analysis/yield gap analysis will be carried out as a sub-activity to come-up with trait prioritization. Information on the supply side of carp research (e.g., increase in productivity due to research, probability of research success, etc.) will be collected from knowledgeable researchers. While information on the demand side will be collected from secondary sources and/or surveys depending on the level of analysis (e.g. secondary data for species level analysis, and surveys for trait level analysis).

In collaboration with ICLARM Socioeconomist, national Socioeconomists(s) in each participating country will: 1) collect, review and compile available information related to carp production and consumption; 2) conduct surveys of carp producers and consumers, and analyze data; 3) estimate fish demand function for various carp species; 4) conduct surveys of fisheries and aquaculture scientists for prioritizing carp genetic research; and 5) prepare research reports on various project activities.

6.3 Genetic improvement of carp species

Selective breeding and line crossing will be utilized to improve growth and reproduction in silver barb *(Puntius gonionotus)* and catla *(Catla catla)* in multiple environments in Bangladesh. Mass selection and gynogenesis will be applied to blunt snout bream *(Megalobrama amblycehala)* and common carp *(Cyprinus carpio)* to improve growth and flesh quality, respectively, in pond and cage polyculture in China. India will use mass selection, hybridization and genome manipulation to improve growth and survival of *Labeo fimbriatus*, in monoculture. Indonesia will evaluate multiple trait selection for growth, disease resistance and delayed sexual maturity of common carp in multiple environments, pond and cage monoculture and in rice-fish ponds. Thailand will test multiple programs such as family selection, monosex production and crossbreeding to improve survival, parasite resistance, growth and body shape in silver barb and common carp in pond polyculture with tilapia. The growth of silver barb, and the growth and appearance of common carp will be improved with monosex production and selection, respectively, in multiple environments in Vietnam.

However, the species, farming systems and traits being considered are preliminary and may be changed based on the results of prioritization exercise being carried out under the socioeconomic component of the project.

7. IMPLEMENTATION ARRANGEMENTS

ICLARM has established a project office at its headquarters in Manila, and formed a multidisciplinary research team composed of its 3 internationally recruited scientists: Dr. Rex Dunham (Geneticist/Project Leader), Dr. Madan Mohan Dey (Fisheries Economist) and Dr. Modadugu V. Gupta (Aquaculturist/Project Coordinator) to provide the necessary support to the various activities of the national research teams, including coordination of overall Project activities, provision of technical backstopping and other necessary support activities.

At the national level, multidisciplinary research teams have been formed by all the six participating countries. Each national team is composed of three working groups (one on each component of the project : documentation of carp genetic resources, socioeconomic and priority setting activities, and genetic improvement and breeding) with scientists drawn from highly recognized research and educational institutes, and has an overall focal point (coordinator). The participating institutions comprise the Bangladesh Fisheries Research Institute, Bangladesh Agricultural University (Bangladesh); Shanghai Fisheries University, Freshwater Fisheries Research Center (People's Republic of China); Central Institute of Freshwater Aquaculture, National Bureau of Fish Genetic Resources, University of Agricultural Sciences, (India); Research Institute of Freshwater Fisheries, Hasanuddin University (Indonesia); National Aquaculture Genetics Research Institute, Fisheries Economics Division of the Department of Fisheries (Thailand); and Research Institute for Aquaculture No. 1, Research Institute for Aquaculture No. 2 (Vietnam). Table 1 shows the names of participating institutions and leaders in each component of the project.

8. PROJECT WORKPLANS

Country-specific project workplans, relative to each component (documentation of genetic resources, socioeconomic and priority-setting activities, and genetic improvement and breeding works) are given in Charts 1 to 6. All participating countries are expected to complete documentation of carp genetic resources by the end of October 1998. The priority-setting activities will be carried out in two stages : prioritization of species , and prioritization of farming systems and traits. All countries, except China and India, would complete the prioritization of species by the end of 1997; China and India are expected to complete this activity by January '98 and February '98, respectively. All participating countries are expected to complete prioritization of farming systems and traits by the end of 1999. All countries, except China and India, are expected to initiate the genetic improvement and breeding activities by January 1998. India and China are expected to initiate this activity by February '98 and March '98, respectively.

Table 1. Participating institutions and team leaders in each component of the Project

Country	Documentation of carp genetic resources		Socio-economic activities		Genetic improvement		Overall focal point
	Institution	Team leader	Institution	Team leader	Institution	Team leader	
Bangladesh	FRI	Dr. M. Gulam Hussain	BAU	Dr. Md. Ferdous Alam	FRI	Dr. M. Gulam Hussain	DG/FRI, Chairman BSERT (BAU)
China	FFRC	Dr. Chen Jiaxin	FFRC	Mr. Miao Weimen	SFU/FFRC	Dr. Li Sifa/ Dr. Chen Jiaxin	Dr. Li Sifa/Director, FFRC
India	NBFGR	Dr. A.G. Ponniah	CIFA	Dr. R.S. Shrivastava	CIFA/UAS	Dr. P.V.G.K. Reddy/Dr. Y. Basavaraju	Director, CIFA
Indonesia	RIFF	Dr. Rudhy Gustiano	Hasanuddin University	Dr. Rahim Darma	RIFF	Dr. Rudhy Gustiano	Director, CRIFI
Thailand	NAGRI	Dr. Nuanmanee Pongthana	FED (DOF)	Ms. Wacherapranee Claithong	NAGRI	Dr. Nuanmanee Pongthana	DG/DOF
Vietnam	RIA No. 1	Dr. Tran Mai Thien	RIA No. 1	Ms. Dinh Kim Nhung	RIA Nos. 1 & 2	Dr. Tran Mai Thien/Dr. Nguyen Van Hao	Director, RIA No. 1

Chart 1. Country-Specific Workplans and Schedules for Socioeconomics and Genetic Activities

Bangladesh

	1997				1998												1999												2000					
	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
1. MOA and other admin formalities	●	●	●																															
2. Documentation of genetic resources	●	●	●	●	●	●	●	●	●	●	●	●	●	●																				
3. Socio-economic activities																																		
a) Compilation of secondary information	●	●	●	●																														
b) Prioritization of species	●	●	●	●																														
c) Selection of sites & preparation	●	●	●	●																														
of questionnaire																																		
d) Collection of other relevant information	●	●	●	●	●	●	●																											
(e.g. NACA dataset)																																		
e) Implementation of surveys						●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●												
f) Preliminary analysis of data and																						●	●	●										
prioritization of farming systems/traits																																		
g) Completion of detailed analysis																								●	●	●	●	●						
4. Genetic Improvement and breeding																																		
a) Development of plans	●	●	●																															
b) Staff and facility development	●	●	●																															
c) Initiation and implementation of work					●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●

Chart 2. Country-Specific Workplans and Schedules for Socioeconomics and Genetic Activities

China

	1997				1998												1999												2000					
	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
1. MOA and other admin formalities	●	●	●																															
2. Documentation of genetic resources	●	●	●	●	●	●	●	●	●	●	●	●	●	●																				
3. Socio-economic activities																																		
a) Compilation of secondary information	●	●	●	●	●																													
b) Prioritization of species	●	●	●	●	●																													
c) Selection of sites & preparation of questionnaire	●	●	●	●	●	●																												
d) Collection of other relevant information (e.g. NACA dataset)	●	●	●	●	●	●	●																											
e) Implementation of surveys							●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●												
f) Preliminary analysis of data and prioritization of farming systems/traits																						●	●	●										
g) Completion of detailed analysis																								●	●	●	●	●						
4. Genetic Improvement and breeding																																		
a) Development of plans	●	●	●	●																														
b) Staff and facility development	●	●	●	●	●																													
c) Initiation and implementation of work						●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●

Chart 3. Country-Specific Workplans and Schedules for Socioeconomics and Genetic Activities

India

	1997				1998												1999												2000					
	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
1. MOA and other admin formalities	●	●	●	●																														
2. Documentation of genetic resources	●	●	●	●	●	●	●	●	●	●	●	●	●	●																				
3. Socio-economic activities																																		
a) Compilation of secondary information	●	●	●	●	●																													
b) Prioritization of species	●	●	●	●	●	●																												
c) Selection of sites & preparation of questionnaire	●	●	●	●	●																													
d) Collection of other relevant information (e.g. NACA dataset)	●	●	●	●	●	●	●																											
e) Implementation of surveys						●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●												
f) Preliminary analysis of data and prioritization of farming systems/traits																						●	●	●										
g) Completion of detailed analysis																								●	●	●	●	●						
4. Genetic Improvement and breeding																																		
a) Development of plans	●	●	●	●																														
b) Staff and facility development	●	●	●	●	●	●																												
c) Initiation and implementation of work							●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●

Chart 4. Country-Specific Workplans and Schedules for Socioeconomics and Genetic Activities

Indonesia

	1997				1998												1999												2000					
	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
1. MOA and other admin formalities	●	●	●																															
2. Documentation of genetic resources	●	●	●	●	●	●	●	●	●	●	●	●	●	●																				
3. Socio-economic activities																																		
a) Compilation of secondary information	●	●	●	●																														
b) Prioritization of species	●	●	●	●																														
c) Selection of sites & preparation of questionnaire	●	●	●	●	●																													
d) Collection of other relevant information (e.g. NACA dataset)	●	●	●	●	●	●	●																											
e) Implementation of surveys							●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●												
f) Preliminary analysis of data and prioritization of farming systems/traits																						●	●	●										
g) Completion of detailed analysis																								●	●	●	●	●						
4. Genetic Improvement and breeding																																		
a) Development of plans	●	●																																
b) Staff and facility development	●	●	●	●																														
c) Initiation and implementation of work					●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●

Chart 5. Country-Specific Workplans and Schedules for Socioeconomics and Genetic Activities

Thailand

	1997				1998												1999												2000					
	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
1. MOA and other admin formalities	●	●	●																															
2. Documentation of genetic resources	●	●	●	●	●	●	●	●	●	●	●	●	●	●																				
3. Socio-economic activities																																		
a) Compilation of secondary information	●	●	●	●	●																													
b) Prioritization of species	●	●	●	●																														
c) Selection of sites & preparation of questionnaire	●	●	●	●	●																													
d) Collection of other relevant information (e.g. NACA dataset)	●	●	●	●	●	●	●																											
e) Implementation of surveys									●	●	●	●	●	●	●	●	●	●	●	●	●	●												
f) Preliminary analysis of data and prioritization of farming systems/traits																						●	●	●										
g) Completion of detailed analysis																								●	●	●	●	●						
4. Genetic Improvement and breeding																																		
a) Development of plans	●	●																																
b) Staff and facility development	●	●	●																															
c) Initiation and implementation of work					●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●

Chart 6. Country-Specific Workplans and Schedules for Socioeconomics and Genetic Activities

Vietnam

	1997				1998												1999												2000					
	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
1. MOA and other admin formalities	●	●																																
2. Documentation of genetic resources	●	●	●	●	●	●	●	●	●	●	●	●	●	●																				
3. Socio-economic activities																																		
a) Compilation of secondary information	●	●	●	●																														
b) Prioritization of species	●	●	●	●																														
c) Selection of sites & preparation	●	●	●	●	●																													
of questionnaire																																		
d) Collection of other relevant information	●	●	●	●	●	●	●																											
(e.g. NACA dataset)																																		
e) Implementation of surveys							●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●												
f) Preliminary analysis of data and																						●	●	●										
prioritization of farming systems/traits																																		
g) Completion of detailed analysis																								●	●	●	●	●						
4. Genetic Improvement and breeding																																		
a) Development of plans	●	●																																
b) Staff and facility development	●	●	●																															
c) Initiation and implementation of work					●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●

APPENDIX 1

Program of Planning Workshop

PLANNING WORKSHOP FOR THE "GENETIC IMPROVEMENT OF CARP SPECIES IN ASIA

26-29 July 1997

Venue: Central Institute of Freshwater Aquaculture (CIFA)
Bhubaneswar, India

PROGRAM

26 July 1997

0800	Departure from Hotel for CIFA
0830 - 1030	Visit to Aquaculture Research Laboratories
1030 - 1100	Tea/Coffee Break
1100 - 1230	Inauguration of Workshop by Honorable Chief Minister *Mr.J.B. Patnaik*
1230 - 1330	Lunch Break

TECHNICAL SESSION I: CARP GENETIC RESOURCES IN ASIA

Chairperson: *Dr. P.V. Dehadrai*
Rapporteurs: *Dr. K.D. Mahapatra and Dr. H.K. Barman*

1330 - 1530	Presentations by:	Bangladesh	- *Dr. M. Gulam Hussain*
		China	- *Prof. Li Sifa*
		India	- *Dr. A.G. Ponniah*
		Indonesia	- *Mr. Rudhy Gustiano*
		Thailand	- *Dr. Nuanmanee Pongthana*
		Vietnam	- *Dr. Tran Mai Thien*
1530 - 1545	Tea/Coffee Break		

TECHNICAL SESSION II: CURRENT STATUS OF CARP GENETICS RESEARCH AND BREEDING PRACTICES IN ASIA

Chairperson: *Prof. Li sifa*
Rapporteurs: *Dr. K.D. Mahapatra and Dr. H.K. Barman*

1545 - 1800	Presentations by:	Bangladesh	- *Dr. M. Gulam Hussain*
		China	- *Dr. Chen Jiaxin*
		India	- *Dr. Y. Basavaraju and Dr. R.K. Mandal*
		Indonesia	- *Mr. Rudhy Gustiano*
		Thailand	- *Dr. Nuanmanee Pongthana*
		Vietnam	- *Dr. Tran Mai Thien and Dr. Nguyen Van Hao*

1800 - 1930	Cultural Program at CIFA Auditorium
2000 - 2130	ICLARM reception at Hotel Kenilworth

27 July 1997

TECHNICAL SESSION III: SOCIO-ECONOMIC ISSUES RELATED TO CARP INDUSTRY IN PARTICIPATING COUNTRIES

Chairperson: *Prof. Md. Ferdous Alam*
Rapporteur: *Dr. R.S. Srivatsava*

0830 - 1000	Presentations by:	Bangladesh	- *Dr. Md. Ferdous Alam*
		China	- *Mr. Miaio Weimin*
		India	- *Dr. R.S. Shrivastava*
		Indonesia	- *Dr. Ir. Rahim Darma*
		Thailand	- *Ms. Wacherapranee Claithong*
		Vietnam	- *Ms. Dinh Kim Nhung*
1000 - 1030	Tea/Coffee Break		

TECHNICAL SESSION IV: RESEARCH METHODOLOGIES AND DEVELOPMENT OF WORKPLAN OUTLINES

1030 - 1045	Research framework for genetic improvement *Dr. Ambekar E. Eknath*
1045 - 1100	Framework for socioeconomics research *Dr. Madan Dey*
1100 - 1230	Group discussion
1230 - 1400	Lunch Break
1400 - 1530	Concurrent sessions on genetics and socioeconomics aspects
1530 - 1545	Tea/Coffee Break
1545 - 1730	Interaction between genetics and socioeconomics workplans

28 July 1997

TECHNICAL SESSION IV: CONTINUATION

0830 - 0930	Summarization of agreed methodologies

TECHNICAL SESSION V: DEVELOPMENT OF COUNTRY-SPECIFIC WORKPLANS

Chairperson: *Dr. Modadugu V. Gupta*
Rapporteur: *Dr. K.D. Mapahatra and Dr. H.K. Barman*

0930 - 1300	Presentations by:	Bangladesh	- *Dr. Md. Ferdous Alam*
		China	- *Prof. Li Sifa*
		India	- *Dr. P.G.V.K. Reddy*
		Indonesia	- *Mr. Rudhy Gustiano*
		Thailand	- *Dr. Nuanmanee Pongthana*
		Vietnam	- *Dr. Tran Mai Thien*
1300 - 1430	Lunch Break		
1430 - 1600	General Discussion		
1600 - 1730	MOA, financial and administrative matters		

29 July 1997

0830 - 1030	Visit to field activities of CIFA
1030 - 1045	Tea/Coffee Break
1045 - 1230	Presentation of agreed methodology/workplans
1230 - 1300	Concluding remarks by ICLARM/CIFA
1300 - 1400	Lunch Break
1400 - 1900	Field trip/sight seeing

APPENDIX 2

List of Participants

PARTICIPANTS

Planning Workshop for the Genetic Improvement of Carp Species in Asia Project

26-29 July 1997

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APPENDIX 3

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TERMS OF REFERENCE OF ICLARM EXPERTS AND NATIONAL TEAMS

A. Terms of Reference for ICLARM Experts

The terms of reference will include, but not necessarily be limited to, the following:

1. Geneticist/Project Leader

The Geneticist/Project leader will be responsible for the overall strategic research thrust on applied fish genetics and breeding. The Project leader will:

(i) assess the current status of carp genetic resources and carp breeding programs in the six participating countries;

(ii) in consultation with international experts, prepare the Project's inception report including detailed workplan, overall implementation schedule, and research procedures and guidelines for Project implementation in each of the six participating DMCs;

(iii) in coordination with implementing NARS, design and implement country specific genetic improvement programs; and

(iv) with assistance from other international experts, prepare the Project Progress report and final report to include all outputs and main findings of the research.

2. Fisheries Economist

The Fisheries Economist will:

(i) develop methodology for prioritizing carp genetic research;

(ii) in collaboration with implementing NARS,

(a) assess how and to what extent existing carp species/strains are valued by different groups of the society (farmers, consumers, landless laborers, etc.),

(b) estimate future demand for various carp species by income groups;

(c) analyze present and future importance of various farming systems including problems and opportunities for increasing production in these environments;

(iii) in coordination with implementing NARS, prepare a prioritized list of species, farming systems and breeding goals; and

(iv) assist Project leader in preparing Progress report and Project Completion report.

3. *Aquaculturist/Project Coordinator*

The Aquaculturist/Project Coordinator will:

(i) organize national teams and contribute to the preparation of the Project inception report in collaboration with Project leader and other international experts;

(ii) in consultation with the other international experts, assist ICLARM's Training Coordinator and Information Division in the preparation of appropriate training materials and in the organization of training programs and regional workshops; and

(iii) ensure compliance with the international code of practices, and quarantine protocols, during fish transfers, if any.

(iv) coordinate exchange visits among the participating countries; and

(v) provide overall coordination to ensure complementarity with other carp genetic research within and outside INGA.

B. Terms of Reference for National Teams in the Six Participating DMCs

The terms of reference for the national teams will include , not necessarily be limited to, the following:

(i) plan and conduct field investigations and prepare topical reports on specific aspects of project component in collaboration with the international experts;

(ii) in collaboration with international experts, assist the national government in prioritizing carp genetic research;

(iii) with assistance from international experts, design location specific genetic improvement research activities based on identified priorities;

(iv) carry out carp breeding program in selected specific sites with the guidance of the international experts;

(v) organize local training workshops whenever necessary; and

(vi) assist the Project leader to prepare and finalize the TA final report.

ANNEX 1

Carp Genetic Resources in Participating Countries

CARP GENETIC RESOURCES IN BANGLADESH

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1. INTRODUCTION

Bangladesh is blessed with unique aquatic resources for fisheries development. Inland fisheries cover an area of 4,459,692 ha of which 90.75% comprise of open waters and 9.25% closed water bodies. The major inland open water capture fisheries are covered by floodplains (2,832,792 ha); rivers and estuaries (1,031,563 ha); beels and haors (114,161 ha) etc. The only reservoir, the Kaptai Lake, has an area of 68,800 ha. The inland closed water fisheries comprise of ponds (146,890 ha), ox-bow lakes (5,488 ha) and coastal shrimp farms (260,000 ha). All these areas have high potential for fish production both by capture and culture oriented management. Beside these, marine fisheries has an extensive potential area in the form of territorial waters (12 Kn. miles), coast line (480 km), continental shelves (85,153 sq. km), coastal polders (873,000 ha) and 200 Kn. miles of EEZ (Table 1). The country is rich in the diversity of various fish species, with nearly 296 fresh and brackish water fish species (including fresh water prawns) and 511 marine water species (including marine shrimps), of which many are important for capture and culture fisheries. The current level of fish and shrimp production (1995-96) is about 1.27 million tonnes, 78% of which comes from inland waters and the rest from marine waters (Fig. 1).

2. BACKGROUND INFORMATION ON DIFFERENT SPECIES OF ENDEMIC CARPS IN THE COUNTRY

Endemic carps can be sub-divided into two sub-groups : i) Major carps (*Catla catla, Labeo rohita, Cirrhinus mrigala, L. calbasu* etc); ii) Minor carps (*L. bata, L. gonius, L. nandina etc.*). Most of the freshwater river systems and floodplains of Bangladesh are the breeding grounds for all the major and minor carps. All these carp species belong to the family Cyprinidae, which are numerous with regard to genera and species (Rahman, 1989). The family includes the groups like carps, barbs and a large variety of minnows. All the major and minor carps, and partly barbs, are commonly called as carps. There are at least 13 species of carps (belonging to carp and barb groups) under 6 genera in the available water system of Bangladesh (Table 2).

All the species belonging to the major carp sub-groups (e.g. catla, rohu, mrigal, calbasu etc.) are the natural inhabitants of the freshwater sections of the rivers of Bangladesh, Burma, Northern India and Pakistan (Jhingran and Pullin, 1985). In Bangladesh, these species are mostly available in Padma-Brahmaputra river system (i.e. Padma, Jamuna, Arial Khan, Kumar and Old Brahamaputra river) and Halda river in Chittagong. Their favourite habitat is the deep pools of these rivers. During the time of monsoon they naturally breed in shallow inundated areas of rivers.

Among the giant carps, mahseer (*Tor* spp.) is an inhabitant of hilly streams of Mymensingh, Sylhet, Dinajpur districts and Kaptai lake of Chittagong Hill tracts. The natural spawning ground of mahseer is sandy bottom, pebbles and aquatic weeds where higher temperature and dissolved oxygen remain (Pathani, 1982).

On the other hand, all the other species belonging to the minor carps (e.g. reba, bata, nandin, gonia, sharpunti etc.) are the natural inhabitant of small rivers and floodplains. Shallow freshwater zones of North-East (Mymensingh and Netrokona), South-West (Faridpur and Jessore) and North-West (greater Rajshahi area) are the favourite habitats of these minor carps. They naturally breed there and grow within a short period of time (10-12 months).

3. HISTORY OF DIFFERENT SPECIES OF INTRODUCED OR EXOTIC CARPS

Although Bangladesh is rich in endemic fish genetic resources, introduction of different varieties of fish species (mostly Chinese carps) has occurred since, 1960. Such introductions have not been properly recorded. Only document so far available is a seminar paper entitled "Introduction of exotic fishes in Bangladesh" written by Rahman (1985). Subsequently, the Bangladesh Fisheries Research Institute (FRI) maintained its record of new fish introductions for research purpose. A list of different species of introduced species of carps is made on the basis of those records and is in Table 3.

Among the introduced carp species, the Chinese carps (silver carp, grass carp, bighead carp, black carp, common carp etc.) and exotic barbs (silver barb and Mahseer) are predominant. Brief history of their introductions in the country is given below:

3.1 Silver carp

Silver carp (*Hypohthalmichthys molitrix*) was first introduced from Hongkong in 1969. In 1970, a second consignment of 282 silver carp juveniles were imported from Japan and shifted to Freshwater Fisheries Research Station, Chandpur (Rahman, 1985).

3.2 Grass carp

The first batch of grass carp (*Ctenopharyngodon idella*) fingerlings were brought to Bangladesh from Hongkong in 1966 and reared in the ponds of Freshwater Research Station, Chandpur. A second batch of 300 fry were imported from Japan in 1970. In 1979 a third batch of fingerlings as well as adults have been introduced from Nepal and kept in Raipur Hatchery Complex, Laxmipur. According to Rahman (1985), these were successfully bred in 1980 and seed were distributed to several seed multiplication farms and Aquaculture Experiment Station, Mymensingh of the Department of Fisheries (DOF).

3.3 Bighead carp

Bighead carp (*Aristichthys nobilis*) fingerlings were imported from Nepal in 1981 and reared in Raipur Fish Hatchery Complex.

3.4 Black carp

About 2000 fry of black carp (*Mylopharyngodon piceus*) were brought from Kwantung Province, China and introduced into Bangladesh by the DOF (Rahman, 1985). These were distributed into several hatcheries including Aquaculture Experiment Station, Mymensingh.

3.5 Common carp

There are three morphologically different strains of common carp viz. i) Scaled carp (*Cyprinus carpio* var. communis); ii) Mirror carp (*C. carpio* var. specularis) and iii) Leather carp (*C. carpio* var. nudus). It has been reported that scaled common carp was first introduced in Bangladesh by DOF in 1960 (Rahman, 1985). Very recently, a batch of 1000 individuals of genetically improved common carp have been brought from Vietnam through ICLARM and transported to Freshwater Station (FS), BFRI, Mymensingh. In 1979, the mirror carp was first introduced in Bangladesh from Nepal and reared in Raipur Fish Hatchery Complex. Francois Rajts (personal communication) reported that the second batch of pure strain of mirror carp was imported from Hungary during the mid of 1980's and successfully bred in Jessore.

3.6 Mahseer

A batch of 1000 fingerlings of *Tor putitora* were transplanted into Bangladesh from Nepal in 1991. The fish were reared in earthen ponds and artificially spawned recently (Mahata et al., 1995).

3.7 Silver barb

Silver barb (*Puntius gonionotus*) was first introduced into Bangladesh from Thailand (Nuruzzaman, 1988) in 1987. Meanwhile, hormone induced ovulation and successful induced breeding technique have been developed in Bangladesh (Hussain et al., 1987). In March 1994, two more consignments of broodstock were introduced in Bangladesh from Thailand and Indonesia through ICLARM Bangladesh Project.

4. STATUS OF WILD AND CULTURED CARP GENETIC RESOURCES

4.1 Habitat degradation and status of endemic wild carp genetic resources

In recent years, natural fish stocks have declined due to degradation of aquatic environments and reduction of many wet-lands and water areas due to natural causes and man-made changes resulting in loss of many habitats of riverine and floodplain endemic fish species. As a result, many valuable indigenous species have been threatened or endangered and some are already on the verge of erosion and extinction (Table 4). Human induced factors causing loss of genetic diversity of fish stocks are water pollution from industrial, agricultural and municipal wastes, and construction of embankments for flood control, and river dams for irrigation and hydro-electric generation. All these factors interfere directly or indirectly with fish migration, reproduction and survival which ultimately affect the bio-diversity in various aquatic ecosystems.

a. Impacts on riverine ecosystem

Bangladesh is a riverine country. The major river systems are Jamuna, Padma, Meghna, Brahmaputra and Tista. Siltation in the upstream part of these rivers is a serious problem which reduces the rate of water flow and navigational capacity. Due to habitat degradation, the spawning and grazing fields of many riverine small fishes have been lost. The sharp decline in natural seed production in most of the rivers is due to above reasons. Dumping of municipal and industrial wastes has also seriously threatened riverine ecosystem. Toxic disposal of sugar and paper mills, tannery industry, fertilizer factories and industries into the Karnaphuli, Rupsha, Buriganga and Shitalokkha river drainages have caused high levels of alkalinity and extensive eutrophication (Safiullah, 1987). It's fact that industrial and other forms of pollution are causing detrimental changes in genetic stock structure of riverine fish populations. Use of gill nets having undesirable mesh size to catch juveniles and young fish by fishermen is a common practice in the country. A concomitant effect has been the change and shrinking genetic base and natural stock structure of riverine and other open water fish population.

b. Impacts on floodplain ecosystem

Floodplains are the major part of inland open water ecosystem covering about 70% of the area. Seasonal wetlands retain water for 4-6 months. For obvious reasons, floodplains are the most suitable spawning and feeding grounds for many freshwater fish species. Wetlands of Bangladesh have suffered form the impacts of burgeoning human population. In the Ganges-Brahmaputra floodplain alone, approximately 2.1 million ha of wetland has been lost due to flood control, drainage and irrigation development (Khan *et al.*, 1994). All the floodplains are naturally connected with deeper water areas like beels and baors. Most of these floodplains and depressions were subjected to rapid natural siltation. Heavy siltation, construction of large number of Flood Control and Drainage (FCD) and Flood Control, Drainage and Irrigation (FCDI) structure have impeded feeding and breeding migration of many important fish species of floodplains resulting in negative effect on the stock recruitment. The estimated total area under floodplains was almost 6.3 million ha in the past, of which 0.81 million ha have been reduced by flood protection measures. Catch rates of these areas have also dramatically reduced. It is estimated that 2.0

million ha of floodplains would be lost to fishery due to water development projects by the year 2005 with a loss of production over 1.0 million ton fish/year.

4.2 Status of cultured carp genetic resources

a. Broodstock management scenario and artificial breeding of carp in hatcheries

Endemic major carps viz. catla (*C. catla*), rohu (*L. rohita*) and mrigala (*C. mrigala*) and Calbasu (*L. calbasu*) are river spawners. For culture, seeds of these species previously used to be collected from natural sources. Naturally available seeds are a mixture of both desirable and undesirable species of fish. Over the last few decades, human ingenuity has made it possible for fish seed production through artificial propagation or induced breeding. Since late 70's, carp seed production through artificial reproduction has become a common practice in Bangladesh. Meanwhile, Chinese major carps were also introduced and a large number of hatcheries estimated over 400 have been established producing about 78,000 kg* of carp spawn (hatchlings) per year and contributing more than 90% of the total spawn production (Fig. 2). Recently, stock deterioration of hatchery population, due to poor broodstock management (i.e. unconscious negative selection or use of undesirable size of breeders for mating) and inbreeding depression (possibly due to sib or parent vs. offspring mating), has been observed. Retarded growth, reduction in reproductive performances, morphological deformities, increased incidence of diseases and mortalities are being reported. A study based on the data on various carp species from several fish hatcheries located at Jessore, Comilla and Mymensingh revealed that most of the hatchery operators have no basic idea about broodstock management aspects viz. recruitment of new breeders at regular interval in the stock, stocking density of breeders, their balanced feeding and water quality maintenance at the fattening ponds. Even, they do not follow any scientific principles in selecting proper size brood fish, injecting adequate hypophysation dosage and mating unrelated male and female spawners etc. Such ignorance of the hatchery operators lead to unconciuos negative selection or use of undesirable size of broodstock and generation after generation mating of spawners from finite populations. As a result, deterioration of carp seed quality has largely occurred. Presumably, a large quantity of such deterrent seeds are used in aquaculture and also stocked in floodplains and other openwater bodies. There is widespread concern that mass stocking of such deterrent stock in floodplains and open waters might cause gene introgression problem in pure wild stocks which would ultimately adversely affect aquaculture and inland openwater fish production in the country. To avoid loss of genetic variation and rapid accumulation of inbreeding in hatchery populations, proper broodstock management and effective breeding plans need to be designed and implemented. Collection of quality and improved fish seeds from known sources and wisely stocking them in floodplains and other open waters certainly will ensure increased fish production.

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*1kg contains ca. 0.4 million hatchlings.

b. Role of different carp species in aquaculture

Polyculture of fish involving different species of carps is an age old practice in Bangladesh. The production was not satisfactory due to lack of scientific knowledge regarding suitable species combinations, optimum stocking densities, use of fertilizers and supplementary feeds. Since 1987, FRI under its Freshwater Station, Mymensingh has conducted both on-station and on-farm research and developed low cost and low input, but highly profitable technologies for the end users (i.e. farmers). Various combinations of 5-7 species of carps at a density of 6000-8000 fish/ha has been recommended (Table 5). Table 6 shows cost and return analysis of polyculture system.

5. CURRENT GENETIC RESEARCH ON CARPS

5.1 Characterization of carps

- Assessment of meristic and morphological characters of different land races of carps (specifically catla and rohu);
- Genetic fingerprinting of riverine stock of catla using molecular technique;
- Genetic fingerprinting of silver barb stocks (Thailand, Indonesian and Bangladeshi);
- Karyotyping to assess ploidy level of rohu and mrigal.

5.2 Stock improvement of carps through genetic manipulation and selective breeding

- Breeding plans for stock improvement of catla;
- Induction of gynogenesis and production of genetic clones in rohu;
- Selective breeding and line crossing of silver barb;
- Monosex female production of silver barb.

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Table 1: Area of different fisheries resources of Bangladesh

Source	Water area
1. **Inland Fisheries**	
(a) Closed Water bodies	
(i) Pond	1,46,890 ha
(ii) Ox-bow lake	5,488 ha
(iii) Coastal Shrimp Farm Zone	2,60,000 ha
Total	4,12,376 ha
(b) Open Water body	
(i) River	10,31,563 ha
(ii) Beel	1,14,161 ha
(iii) Kaptai lake	68,800 ha
(iv) Flood plain	28,32,792 ha
Total	40,47,316 ha
Grand Total (a + b)	44,59,692 ha
2. **Marine Fisheries**	
(i) Territorial water	12 kn. miles
(ii) Exclusive economic zone	200 kn. miles
(iii) Coast line	480 km.
(iv) Continental shelf	85,153 kq.km.
(v) Coastal polder/encloser	8,73,000 ha

Table 2: List of endemic carp and barb fishes of Bangladesh.

Family	Species	Common name	Local Name
Cyprinidae	*Catla catla*	Catla	Katla
	Labeo rohita	Rohu	Rui
	Cirrhinus mrigala	Mrigal	Mrigala
	Labeo calbasu	Calbasu	Kalibaush
	Cirrhinus reba	Reba	Bhangna
	Labeo bata	Bata	Bata
	Labeo boga	Boga	Bhangan
	Labeo gonius		Ghonia
	Labeo nandina		Nandil
	Rashbora elonga		Elong
	Puntius sarana	Barb	Sarpunti
	Tor tor	Tor mahseer	Mahashol
	Tor putitora	Golden mahseer	Mahashol

Source : Hasan (1990), Rahman (1985)

Table 3: List of introduced or exotic carp and barb fishes available in Bangladesh.

Family	Species	Common name	Source	Year of Introduction
Cyprinidae	*Ctenopharygodon idella*	Grass carp	Hong Kong Nepal Japan	1966 1979 1970
	Hypophthalmichthys molitrix	Silver carp	Hong Kong	1969
	Aristichthys nobilis	Bighead carp	Nepal	1981
	Mylopharyngodon piceus	Black carp	China	1983
	Cyprinus carpio var. Communis	Common carp	China Vietnam	1960 1995
	Cyprinus carpio var. Specularis	Mirror carp	Nepal	1979
	Puntius gonionotus	Silver barb	Thailand Thailand Indonesia	1987 1994 1994
	Tor putitora		Nepal	1991

Source : Hasan (1990), FRI (1997), Rahman (1985)

Table 4: A list of endangered inland freshwater species of fish in Bangladesh.

Group	Name of species	Local name
Carp	*Labeo gonius* *Labeo nandina* *Cirrhina reba* *Puntius sarana* *Tor tor* *Tor putitora*	Ghainna, Kurchi Nandina, Nandil Bhangna, Bata Sarpunti Mohashol, Mahseer Mohashol, Mahseer
Catfish	*Pangasius pangasius* *Mystus cavasius* *Batasio tengara* *Ompok bimaculatus* *Ailia coila* *Ailiichthys punctata* *Pseudetropius atherinoides*	Pangash Golsha tengra Tengra Madhu pabda Baspata Kajuli Batashi
Loach	*Botia dario* *Lepidocephalus guntae*	Rani Gutum
Spiny ell	*Macrognathus aculeatus* *Mastacembelus pancalus*	Tara baim Chirka
Whiting	*Nandus nandus* *Badis badis*	Meni, Bheda Napit
Gormy	*Colisha faciatus* *Colisha lalius*	Khalisha Lal khalisha
Glass perch	*Chanda nama* *Chanda ranga*	Nama chanda Lal chanda
Mullet	*Rhinomugil corsula*	Khalla

Table 5: Combinations of different species of carp in polyculture in Bangladesh

Species	Model-1	Model-2	Model-3
Silver carp	20	10	30
Catla	10	30	10
Rohu	15	30	30
Mrigal	15	20	20
Grass carp	10	10	10
Common carp	5		
Silver barb	25		

Source : Mazid *et al.* (1993)

Table 6: Annual per hectare cost and return in polyculture system

Item	Amount	Price
Cost:		
1. a) Pond construction & repair	1 hectare	7500.00
b) Labour	-	6500.00
2. a) Phostoxin	750 Nos.	1975.00
b) Lime	250 kg	750.00
c) Fingerlings	6000 Nos.	6000.00
3. Fertilizer:		
a) Organic manure	25000 kg	7500.00
b) Inorganic fertilizer (Urea + TSP)	1200 kg	7800.00
4. Feed:		
a) Rice bran	4500 kg	11250.00
b) Mustard oil cake	1500 kg	9000.00
5. Netting	-	1000.00
6. Other costs	-	1000.00
Net cost		60,275.00
7. Bank interest	16%	9,616.00
Income : Fish sale	5000 kg	175,000.00
	(Tk. 40/kg Fish)	200,000.00
Net Income (200,000-69,919.00)		130,081.00

CARP GENETIC RESOURCES IN CHINA

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1. GENERAL DESCRIPTION

In China, the reported number of fish species is 3,016, of which more than 300 species belong to Cypriniformes. In about 8,000 freshwater fishes of the world, Cypriniformes is the largest group (30%) with over 2,400 species.

In China, there are more than 800 freshwater fishes, of them, 40% belong to Cypriniformes (Table 1). Carps play a very significant role not only in capture fisheries, but also in aquaculture. Of the freshwater fish species cultured, 50% are cyprinids (Table 2). Less than 10 species contribute over 80% of aquaculture production in China (Table 3).

Genetic characterization of major chinese carps, including silver carp, bighead, grass carp, black carp, common carp, crucian carp,blunt snout bream has been done during the last 16 years; their genetic standards have been certified recently. For details, please see the book *Genetical Characterization of Major Freshwater Culture Fishes in China* (1997, Shanghai Scientific Press. In press).

2. DESCRIPTION BY SPECIES/GROUPS

2.1 Common carp

Common carp is the fourth most important species in Chinese freshwater aquaculture production. In 1996, its production reached 1,590,000 tones.

2.1.1 Classification

Common carp is regarded as the only species in its genus *Cyprinus*. The various geographical races of common carp have been assigned to different subspecies. Kirpichnikov (1967) divided the common carp into four subspecies, e.g., (1) *Cyprinus carpio carpio* of the European-Transcaucasian area; (2) *C.c. aralensis* of the mid-Asian region; (3) *C.c. haematopterus* of the Amur-Chinese or far Eastern region, and; (4) *C.c. viridivio-laceus* of north Vietnam.

Table 1: Freshwater fish composition in four major sub-regions of China.

	Sub-regions				
	Pearl*1	Jianghuai*2	Hehai*3	Heilongjiang*4	Mean
Freshwater fishes					
Family	17	22	16	19	
Genus	102	106	71	63	
Species	195	245	110	98	
Cyprinidae					
Genus	65	64	45	34	
% of total	64	60	63	54	60
Species	121	140	72	57	
% of total	62	57	66	58	61
% of each subspecies in *Cyprinidae*					
Barbinae	35.54	16.42	1.39	–	
Gobioninae	14.05	27.14	20.83	35.09	
Abramidinae	19.8	19.29	37.50	21.05	
Cyprininae	9.92	2.14	2.78	3.51	
Leuciscinae	9.09	10	13.89	24.56	
Acheilognathinae	5.79	12.14	12.50	8.77	
Xenocyprinininae	3.31	7.14	5.56	3.51	
Gobiobotonae	0.83	4.29	2.78	1.75	
Number of species					
Cobitidae	22	16	10	2	
Homalopteridae	15	12	–	–	
Bagridae	7	24	5	4	
Ophiocephalidae	7	5	1	–	
Siluridae	3	1	–	2	
Claridae	3	1	–	–	
Amblycipitidae	–	3	–	–	
Cobitidae		2	6	–	
Serranidae	7	8	2	–	

*1 Pearl sub-region: Pearl River basin basically
*2 Jianghuai: Yangtze River basin + Huihe River basin
*3 Hehai: Yellow River basin + Haihe River basin
*4 Heilongjiang: Amur River basin basically

Table 2: Freshwater fish species/subspecies cultured in China
(*represents carps)

Common name	Scientific name
1. Silver carp*	*Hypophthalmichtys molitrix*
2. Bighead carp*	*Aristichtys nobilis*
3. Grass carp*	*Ctenopharyngodon idella*
4. Black carp*	*Mylopharyngodon piceus*
5. Mud carp*	*Cirrhiona moliterella*
6. Common carp*	*Cyprinus carpio*
7. Mirror carp*	*Cyprinus carpio*
8. Crucian carp*	*Carassius auratus*
9. Silver crucian carp*	*Carassius auratus cuvieri*
10. White crucian carp*	*Carassius auratus gibelio*
11. Blunt snout bream*	*Megalobrama amblycephala*
12. Black bream*	*Megalobrama terminalis*
13. White Amur bream*	*Parabrama pekinensis*
14. Eastern bream*	*Abramis brama orientalis*
15. Silver small scale*	*Xenocypris argentea*
16. Freshwater yellowtail*	*Xenocypris davidi*
17. Round snout*	*Distoechodon tumirostris*
18. Small scale*	*Plagiognathos microlepis*
19. White fish	*Leuciscus waleckii*
20. Japanese eel	*Anguilla japonica*
21. Mandarin fish	*Siniperca chautsi*
22. Snakehead	*Ophiocephalus argus*
23. Snakehead	*Channa asiatica*
24. Tench*	*Tinca tinca*
25. Grey mullet	*Mugil caphalus*
26. Red-eyed*	*Mugil soiny*
27. Rainbow trout	*Salmo gairdneri*
28. White fish	*Coregonus peled*
29. Nile tilapia	*Oreochromis niloticus*
30. Blue tilapia	*O. aureus*
31. Mozambique tilapia	*O. mossambicus*
32. Local catfish	*Clarias fuscus*
33. Leather catfish	*Clarias lazera*
34. Magur	*Clarias batrachus*
35. Rohu*	*Labeo rohita*
36. Largemouth bass	*Micropterus salmoides*
37. Sea bass	*Lales calcarifer*
38. Channel catfish	*Ictalurus punctatus*
39. Brown bull head	*Ictalurus nebulosus*
40. European catfish	*??*
41. Freshwater pompano	*Colossoma brachypomum*
42. Paddy eel	*Monopterus ahbus*
43. Loach	*Misgurnus anguillicandatus*
44. Roach*	*Rutilus rutilus*

Table 3: Aquaculture production of major cultured carps in the world and China (1994)

Species	World production (X 1000 tons)	Proportion in world total	China's production (X 100 tons)	China's proportion
Silver carp	2,210	17.56	11,193**	97.3
Grass carp	1,819	14.45	1,790	98.4
Common carp	1,527	12.13	1,128	73.9
Bighead carp	1,072	8.52	?	
Rohu	440	3.18		
Crucian carp	389	3.09	385	99
Catla	361	2.87		
Mrigal	354	2.81		
Wuchang fish	281	2.23	281	100
Black carp	105	0.83	105	100
Mud carp	100	0.79	100	

*Source: FAO; Li Sifa, 1996
**Includes bighead carp also.

Many varieties have been developed in common carp. Subclassification according to scale pattern into scaled carp, mirror carp and leather carp is popular in carp aquaculture, but not justified for taxonomy bcause all scale patterns may segregate from the same spawn, as a result of their simple Mendelian inheritance. Mirror carp are preferred in Europe. Another subclassification according to colors also not justified for same reason.

There are numerous varieties and subvarieties or strains of common carp in China. Such as the well known variety of the Xingguo red common carp, red purse common carp in Jiangxi Province, "Long bodied" common carp in the Yangtze River Basin, and the "big belly" common carp in southern China. Scaled carp are preferred in China and Asia.

2.1.2 Origin

The common carp probably originated in Asia and the area of the Caspian Sea at the end of the Pleistocene era (Steffens 1966; Balon 1974). From there it spread east and west during the last post-glacial period. In the easterly direction it reached China, but did not cross the Bering land bridge to America. Its westerly migration reached the Black and Aral Seas, arriving at the Danube River system some 10,000 years ago. The species did not extend north to Britain and Scandinavia (Balon 1974).

The original natural distribution of common carp is probably restricted to a narrow belt in Central Asia within latitudes of 35° - 50°N and longitudes of 30° - 135°E and the altitude generally 300 m above mean sea level (Jhingran and Pullin 1985).

2.1.3 Introduction

The common carp has been introduced in the world very widely, and has been summarized by Welcomme (1988). In most cases for aquaculture, but some times for sport or as ornamental fish.

Within China, the introduction is even frequently among river basins and districts.

2.1.4 Domestication

The common carp is probably the most domesticated fish not only in China but also in the world. Within this main framework of domestication, a large number of so-called races, strains and varieties have been developed (Table 4). The crossbred common carp often exhibit heterosis for growth rate and disease resistance.

Table 4: Summary information on some important strains of the common carp in China.

Name	Location	Appearance	Performance
Big belly	Southern China	Scale, deep-bodied	Widely cultured in China
Red purse	Jiangxi Prov. China	Scale, deep-bodied	Limited use in culture, important as a genetic resource
Xingguo red	Jiangxi Prov. China	Scale, long-bodied	Limited use in culture, important as genetic resource
Wild	Central/East Asia	Scale, long-bodied, variable color	Performs poorly in culture, important as genetic resource

2.1.5 Genetic characterization

Genetic characterization of common carp has been done for red purse, xingguo red and mirror common carps, in detail.

2.1.6 Selection

In 1970s, many hybridization studies of common carp were made. The F1 hybrids produced from different races/stocks of common carp usually exhibit heterosis and are welcomed by farmers, such as "harvest carp", "heyuan carp", "triple-cross carp", "yue carp", "furong carp". Considering the genetic pollution to the wild stocks by the hybrids, hybridization of common carp is no longer conducted.

Jian carp was produced by combined techniques of hybridization and selection, and is widely cultured.

2.1.7 Conservation

Three conservation stations for red purse, xingguo red, and amur wild common carps have been established.

2.2 Crucian carp

The crucian carp is a native of the temperate regions of Asia, especially in China.

Crucian carp is the sixth most important species in Chinese freshwater aquaculture production. In 1996, its production reached 690,000 tones.

2.2.1 Classification

The various geographical races of crucian carp have been assigned to different subspecies/stocks (Table 5).

Table 5: Brief information on important stocks of the crucian carp in China

Name	Location	Appearance	Performance
Silver crucian carp *(C.a. gibelio)*	Amur River Basin	Deep bodied	Natural triploid
Pengze crucian carp *(C.a. var. Pengzenensis)*	Yangtze River Basin	Lower bodied	Natural diploid
White crucian carp *(C.a. Cuvieri)*	Lake Japan. Introduced into China in 1976	Deep bodied	Plankton feeder

2.2.2 Origin

The crucian carp probably originated in Asia, particularly in China. Silver crucian carp *(Carassius auratus gibelio)* is a local subspecies living in Helongjiang (amur) River Basin. It is a very valuable genetic resource because it is the well known natural triploid strain in natural carp populations or commonly cultured carp species.

Pengze crucian carp *(Carassius auratus* var. *Pengzenensis)* is a local subspecies living in several lakes along the middle reach of Yangtze River in Jiangxi Province. Unlike the naturally occurring triploid *C. auratus gibelio*, the Pengze crucian carp is a diploid.

2.2.3 Introduction

Silver crucian carp and Pengze crucian carp have been widely introduced and cultured in different parts of China. They are easily crossed with local crucian carp, so their brood stock has to be carefully maintained.

White crucian carp was introduced into China from Japan in 1976, and was popularized in aquaculture for several years. Because of poor taste and low disease resistance, this stock is no longer cultured in China as principle species.

2.2.4 Genetic characterization

Taking silver crucian carp as a model, crucian carp's genetic characterization has been studied in detail (Li Sifa 1997).

2.2.5 Conservation

Two conservation stations have been established for silver crucian carp and pengze crucian carp.

2.3. "Chinese carps"

Silver carp *(Hypophthalimichtys molitrix),* bighead carp *(Aristichthys nobilis),* grass carp *(Ctenopharyngodon idellus)* and black carp *(Mylopharyngodon piceus)* are called popularly in China as "Four Chinese Farmed Fishes". In 1996, the culture production of silver carp and bighead carp reached 4,200,000 tones, grass carp reached 2,400,000 tons, and the black carp reached 119,000 tons.

On the other hand, the natural resources of "Chinese carps" are decreasing. In the Yangtze River, commercial fishing yield of Chinese carps in 1980s was only half of 1950s; their fry yield in 1980s was one fourth of 1960s.

2.3.1 Origin

Silver carp, grass carp and black carp are distributed in the Yangtze, Pearl and Amur Rivers. Bighead carp is distributed in the Yangtze and Pearl Rivers. In 1960, bighead carp was introduced into the Amur River and has formed a local population there.

Bigscale silver carp *(H. harmandi),* a close species of silver carp, is distributed in Hainan Island and the Red River. Unfortunately, it has become extinct from the Hainan Island during 1970s.

2.3.2 Domestication

Genetically, there are no domestic strains of "Chinese carps".

2.3.3 Genetic evaluation

The genetic characterization of "Chinese carps" has been studied in detail since 1980s (Li Sifa et al. 1990; Li Sifa 1997).

2.3.4 Management of genetic resources

Seven stocks of farm originated "Chinese carps" have been established in the Yangtze River basin.

2.4 Blunt snout bream (Wuchang fish)

Blunt snout bream *(Megalobrama amblycephala)* from nature was introduced into large area as a principal culture species in 1960s. Its production reached 380,000 tons in 1996.

2.4.1 Origin

Blunt snout bream is distributed in several large– and middle–size lakes along the middle-reach of the Yangtze River.

2.4.2 Domestication

Many hatchery populations have formed in different areas. Degeneration has been observed. Selection studies were started in 1980s and the 5th generation has been produced and shows good response.

2.4.3 Genetic characterization

Genetic characterization study has been done (Li 1997).

2.4.4 Conservation

One conservation area for blunt snout bream has been established.

2.5 Mud carp

Mud carp *(Cirrhina molitorella)* is distributed in the Pearl River basin. It is one of the major culture species in the southern China. For example, in 1994, the freshwater fish culture production of Guangdong Province was 1,320,000 tones, in which the mud carp production was 204,000 tones.

3. PROBLEMS OF CARPS

3.1 High stress

3.1.1 Decreased diversity

With the overall rapid development of the country and owing to the ever increasing demand for fish as food, aquatic ecosystems are under constant pressure of man-induced stresses. A serious threat to this development is the decrease of diversity.

A preliminary estimate is that there are 98 fish species (9 orders, 24 families and 80 genera) either extinct, endangered or threatened in China (Le, 1991, cited in Li, 1992). For example:

Extinct
1. *Cyprinus yilongenesis*
2. *Anabarilius albumops*
3. *A. ploylepis*

Endangered
1. *Schizothorax taliensis*
2. *S. biddulphi*
3. *Cyprinus longipectoralis*
4. *C. crassilabris*
5. *C. megalophthalmus*
6. *Barbodes exigiua*
7. *B. coggili*
8. *B. exigua*
9. *Psephurs gladius*
10. *Aspiorhynchus laticeps*
11. *Macrura reevesi*

Threatened
1. *Myxocyprinus asiaticus*
2. *Acipenser sinensis*

3.1.2 Aquaculture impacts

(1) *Moving:* In order to meet the demand of development of aquaculture in different areas of China, fish fry and/or fingerlings are transferred in a large scale and very frequently. This may disturb the local fish population/stocks.
(2) *Hatchery population/genetically modified organisms:* Affect on the genetic diversity of wild populations by escapement and introduction of non-native aquacultured organisms, genetically modified organisms (GMOs) into habitat.

3.2 Genetic conservation

Due to the high demand of large population and the rapidly developing aquaculture industry, aquatic biodiversity in china is under a very high stress. Loss of biodiversity throughout China will severely limit the sustainable development of aquaculture and fisheries. Genetic conservation of aquatic organisms becomes a critical problem for the sustainable development of aquaculture industry. Some efforts have been made by the government, fisheries scientists and fisheries communes, but not much.

It is well recognized that the application of genetic principles to aquaculture is far behind that of agriculture or animal husbandry. Conservation of genetic resources will bring long-term benefits to the development of aquaculture in China and the world.

The National Committee of Aquatic Varieties Certification (NCAVC) was established in 1991 under the Ministry of Agriculture. By certification and authorization of NCAVC, 24 national farms for wild and domesticated aquatic organisms farms have been established to maintain and produce better brooders to produce better seed (Table 8).

Table 8: Established and being established pond type gene pool in China

Farm	Location	Species
1. Hanjiang Yangtze River Origin "Chinese carps" farm	Jiangsu Province	"Chinese carps"
2. Wuhu Aquatic Origin Farm	Anhui Province	"Chinese carps"
3. Ruichang Yangtze River Origin "Chinese carps" farm	Jiangxi Province	"Chinese carps"
4. Laohe Yangtze River Origin "Chinese carps" farm	Hubei Province	"Chinese carps"
5. Laohekou Yangtze River Origin "Chinese carps" farm	Hubei Province	"Chinese carps"
6. Changsa Origin Fish Farm	Hunan Province	"Chinese carps" (Xiangjiang River)
7. Jiaxing Fish Farm	Zhejiang Province	"Chinese carps"
8. Jiujiang Pangze Crucian Carp Farm	Jiangxi Province	Pangze crucian carp
9. Fangzheng Crucian Carp Farm	Heilongjiang Province	Fangzheng crucian carp
10. Heilongjiang Wild Carp	Heilongjiang Province	Heilongjiang wild carp
11. Liangzihu Blunt Snout Bream Origin Farm	Hubei Province	Blunt snout bream
12. Guangdong Tilapia Farm	Guangdong Province	Nile tilapia
13. Nanjing Tilapia Farm	Jiangsu Provice	Nile tilapia
14. Qingduo Tilapia Farm	Qingduo	Nile tilapia
15. Mud Carp Farm	Guangdong Province	Mud carp
16. Wuyuan Red Purse Carp Far	Jiangxi Province	Wuyuan red carp
17. Xingguo Red Carp	Jiangxi Province	Xingguo red carp
18. Fangchang River Crab Farm	Anhui Province	River crab
19. Panjing River Crab Farm	Liaoning Province	River crab
20. Changsa Soft-shelled Turtle	Hunan Province	Soft-shell turtle
21. Shaoxing Soft-shell Turtle Farm	Zhejiang Province	Soft-shell turtle
22. Yantai Kelp Farm	Shangdong Province	Kelp
23. Qidong Zicai Farm	Jiangsu Province	
24. Hainan Aquatic Seed Farm	Hainan Province	Fish, Shrimp

The Chinese carps are priority species for genetic conservation. The reason is that they are the backbone of freshwater aquaculture industry in China, contributes two thirds of production in Chinese freshwater fish culture.

The fish diversity of the Yangtze River is a priority area for genetic conservation efforts, considering that the fish production from the Yangtze River basin accounts for 60% of the total freshwater fish production in China. The

Yangtze River is not only the cradle of Chinese fish culture, but also is the prime world site for genetic diversity of Chinese carps, as well as it is the major source of wild brooders for artificial breeding and for ensuring the genetic variability of Chinese carps culture.

3.3 Genetic improvment

Most present aquaculture enterprises are generally based on wild, undomesticated stocks, and in some situations there is evidence for genetic deterioration. The science of aquaculture genetic improvement is still in its infancy in China.

Just as modern production systems for agriculture crops and livestock have depended heavily on efficient breeding and genetic selection programs and the improvement of breeds, genetic improvement programs can make major contributions to increasing productivity and production efficiency in aquaculture.

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CONSERVATION OF CARP GENETIC RESOURCES OF INDIA

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INTRODUCTION

Carps as a group constitute an important component of India's rich fish biodiversity. Not only they support natural fishery substantially but Indian major carps, and certain minor and exotic carps are major Indian aquaculture species. The breakthrough in their polyculture resulted in the blue revolution in the country. Though Indian major carps, catla, rohu and mrigal are not endangered, other carps like *Labeo dero, L. dussumieri, L. fimbriatus* and *L. gonius* are on the endangered species list. Many of the endangered carps are from peninsular region and some are endemic only to India. Rohu, catla and mrigal might not be under threat, however, they are prone to loss of genetic diversity and variability due to extinction of genetically distinct wild populations, escape and ranching of farmed seeds and competition from exotic carps. This paper highlights the importance of conservation of individual species and the genetic diversity within the species. The paper has been divided into three major parts namely; indigenous and exotic carp species in India, prerequisites for conservation of carp germplasm resources, and genetic threats faced by Indian carp resources.

GERMPLASM RESOURCES

Indigenous carps species

Of the indigenous carp species, Indian major carps, *Labeo rohita, Cirrhinus mrigala* and *Catla catla* are widely cultured than others. These have been introduced into peninsular India where they were originally not found and could have led to endangering endemic peninsular carps. Information on indigenous Indian carps is widely scattered and some information from Jhingran (1984) on the world distribution, growth under farm and wild conditions for the important Indian carp species belonging to the genera *Catla, Cirrhinus* and *Labeo*, are given below:

- *Catla catla* (Hamilton): Occurs in India, Pakistan and Burma, introduced into many countries and in peninsular drainages. Important component of composite fish culture. Faster growing of the Indian major carp. Grows to 38-45 cm and 900 g in first year and 4-5 kg in the second year.

- *Cirrhinus mrigala* (Hamilton): Found in freshwaters of India, Burma, Pakistan; more common in plains of North India. Attains maturity at +2 years (344 mm) in the wild and at one year in ponds.

- *Labeo rohita* (Hamilton): Occurs in freshwaters of Pakistan, Burma and India where it occurs in Punjab, U.P., West Bengal, Assam, Orissa, Madhya Pradesh and Ahmedabad. Maximum size recorded is 1030 mm.

- *Labeo calbasu* (Hamilton): Found in the streams of Punjab, West Bengal, Orissa and part of South India. It is more abundant in rivers above tidal reach and lakes.

- *Cirrhinus reba* (Hamilton): Found throughout India. Males mature when 8-13 cm long; females at 23-25 cm long in their first year of life. Grows to 24 cm in length in West Bengal; further south it grows to 38 cm or more in ponds.

- *Labeo dero* (Hamilton): Occurs in Assam, Darjeeling, eastern and western Himalayas, Punjab and Uttar Pradesh.

- *Labeo dyocheilus* (McClelland): Common in Assam and Nepal Himalayas and grows up to 91 cm in length.

- *Labeo fimbriatus* (Bloch): Commonly called as fringe-lipped carp. Occurs in freshwaters of E. Punjab, U.P., Orissa, M.P., Madras, Deccan, Poona, Ahmedabad and Pakistan. It is cultivated in ponds along with other carps in India. Grows to about 23 cm and 450 g in one year and 31 cm in second year.

- *Labeo kontius* (Jerdon): Known as Cauvery carp. It occurs in rivers of south India. It is cultivated in ponds and grows to 23-30 cm and 330 g in one year. Being a hardy fish, it can tolerate polluted waters. Females mature at 30 - 36 cm and males at 27 cm.

- *Labeo bata* (Hamilton): Found normally in north India and Pakistan. It is cultured along with major caps.

- *Labeo gonius* (Hamilton): Freshwaters of India, Pakistan and Burma. In Assam, it is cultured in ponds.

Exotic carp species

The Chinese silver carp, *Hypophthalmichthys molitrix* and grass carp *Ctenopharyngodon idella* are carps of Chinese river basins of south and central China and Amur basin of USSR that have been introduced into India and integrated into composite fish culture practices, with promising results. Silver carp has been found to grow to about 5 kg within the two years in reservoirs. Accidental entry of silver carp into Govindasagar reservoir during flood in 1971 led to the establishment of naturalized population and the decline in fishery of catla and rohu.

The Prusian strain of common carp from Sri Lanka was introduced in 1935 in Nilgiris. The three varieties introduced were the mirror carp *(Cyprinus carpio* var. specularis*)*, scale carp *(C. carpio* var communis*)* and leather carp *(C. carpio* var nudus*)*. The Bangkok strain of common carp was introduced from Bangkok in 1957 for culture in plains. At present, there has been mixing of both strains and they are found as naturalized populations in many parts of India. In the hill region, what is presently popularly called mirror carp is actually the scale carp. Mirror and leather carp occur only in few wild population. Introduction of common carp into Dal Lake in Kashmir has led to sharp decline in native populations of snow trouts.

Besides these, the big head carp *(Aristichthys nobilis)* mud carp *(Cirrhinus molitorella)* and snail carp *(Mylopharyngodon piecus)* have found unauthorized entry into India. Since the feeding habits of these fishes clash with the native fishes, spread of these fishes can endanger indigenous carp species.

PREREQUISITES FOR CONSERVATION

The prerequisites for conservation of carp germplasm resources of India are many. The institutional research support for such activity is available with the National Bureau of Fish Genetic Resources (NBFGR) and the Central Institute of Freshwater Aquaculture (CIFA). Prioritized requirements are given below to effectively utilize this research base.

Database: The conservation strategy for any aquatic species depends on its biology, genetic diversity within and between different populations and stresses that are modifying each population. One of the impediment to conservation of carp germplasm resources of India is the lack of database on the above aspects.

Present status: Only for a few aquatic species like rainbow trout, tilapia and common carp, there is substantial information on genetics. For others like Indian major carps, genetic information is inadequate and biological information from different geographic populations of each species is limited. The importance of studying the different life history traits and population biology of Indian carps has not been adequately addressed and only limited information is available on these aspects. Differences between populations can reflect adaptive response due to different habitats. Information on this coupled with genetics will form the basis on which prioritization of populations within a species can be undertaken for conservation. Also, this data base can be utilized in selection of founder stocks for genetic upgradation programs. At present other than FAO synopsis and ICLARM Fish Base, no detailed database is available.

Future projection: For conservation of germplasm resources of cultured carps, what is required is the collection of information and building a database on the pattern of trout brood stock database on registry for six species of trout. At National Bureau of Fish Genetic Resources, work is presently being carried out on cataloguing available biological and genetic information in a computer format which will ultimately be available online and CD-ROM. However, the non availability of published information is a limiting factor. There is need to give priority and adequate funding for the study of the life history traits, ecology, population dynamics and genetics of each carp species.

STOCK IDENTIFICATION

Description of the genetic diversity in a species is a basic requirement for management of its genetic resources. Initially, studies should be aimed at genetic confirmation of the species as described by morphological methods. Then quantification of genetic variation within a population and between geographic populations can lead to identification of discrete breeding units which have been variously termed as stocks, strains, etc.

Present status: Genetic characterization can be carried out by cyto, biochemical and molecular genetic studies. Compared to biochemical and molecular genetic studies more number of Indian species are cytogenetically screened. Cytogenetic studies can be used to detect two types of chromosomal variations namely chromosome number and karyotype. At NBFGR, a number of species including the Indian major carps have been cytogenetically investigated. Indian major carps have the same diploid number of 50 and no intraspecific variation in chromosomal number has been detected. Among the different banding techniques, NOR, C, BrdU replication banding have been achieved at NBFGR. The chromosomal banding technique of NOR has been studied in 17 different endangered and commercial fishes. Of these, the carp species studied are *C. catla, L. rohita, L. calbasu* and *L. bata*. With the exception of catla which has two pairs of NOR, other Indian major carps have only one pair. In *Cyprinus carpio* var. specularis from Bhimtal Lake of Kumaon Hills, U.P., NOR was observed in the terminal end of one pair of large size metacentric chromosome. While NOR polymorphism has been detected in *Schizothorax richardsonii*, no intraspecific variations have been observed from both riverine and hatchery populations of *L. rohita*. C band have been studied in *L. rohita* and *L. calbasu*.

Using limited number of isozyme systems, electrophoretic studies have been carried out in Indian major carps. At NBFGR, detailed biochemical genetic characterization using 25 enzyme systems is being carried out in 15 prioritized commercial and endangered species. Among the carps, detailed studies have been carried out in *L. rohita, C. mrigala* and *C. catla* and limited studies in *L. calbasu* and *Cyprinus carpio*. Compared to the air breathing fishes, *Heteropneustes fossilis* and *Clarias batrachus* which reveal differences at more or less all the enzyme systems screened, the Indian major carps exhibit a few species specific markers indicating that it is a closely related genetic group.

In normal sodium dodecul sulphate acrylamide (SDS-PAGE), only minor differences could be observed between catla and rohu. However, striking differences were observed in the gradient SDS-PAGE electrophoretic profile of catla and rohu with the catla having more number of bands. All the protein bands were observed within the range of 14,000 to 94,000 daltons. In rohu and mrigal studies to differentiate multi loci estrase system with seven substrates revealed very little substrate specificity. However, with five inhibitors it was possible to characterize the multi loci estrase system. For genetic characterization of endangered fish and valuable brood stock, non invasive and minimum invasive sampling have been carried out with *H. fossilis*. For non invasive sampling, mucus has been used and for minimum invasive sampling, barbel, fin, gill and blood were screened. Majority of the enzyme systems could be screened using these tissues without killing the fish. This technique is also being standardized for Indian major carps.

Using ultrathin (0.1 mm) isoelectric focusing of eye lens protein (IEF-EL), species specific profiles of *L. rohita, L. bata, C. carpio, C. mrigala* and *C. catla* could be obtained. Though the overall number of bands did not vary significantly (24 to 27), there were variations between species with regard to position of bands and even in those bands having common isoelectric focusing point, the intensity varied greatly giving an overall distinct pattern for each species. In *L. rohita* polymorphism could be detected in natural populations from Rapti and Ganga river systems. Differences were observed in the common carp stocks of Ooty and West Bengal in their IEF-EL profile indicating that these two stocks are genetically different. Haemoglobin IEF of nine species including the carps rohu, mrigala and common carp revealed multiplicity of bands and a species specific pattern. Here, IEF has an edge over normal PAGE, which can resolve only one common haemoglobin band for three Indian major carps. This study indicated that haemoglobin IEF like IEF-EL can serve as a good genetic marker for scoring intra population differences. For identifying DNA markers in fish, Indian laboratories have started working with restriction fragment length polymorphism (RFLP) and PCR-based DNA fingerprinting techniques.

Future projection: With the successful development of many isozyme and isoelectric focusing markers, NBFGR has initiated studies to genetically characterize different geographic wild populations of rohu. In collaboration with CIFA, the founder stocks used in the cross breeding and selection programs of rohu are also being genetically typed. Having realized that chromosomal banding technique will require metaphase spread from cultured cells, facilities for cell culture have been established at NBFGR and studies have been initiated. For fish genetic characterization, the chromosome painting technique of FISH may need to be utilized. Under the genetic fingerprinting center set up at NBFGR, priority has been given to the study of Indian major carps.

GENE BANKING

Present status: At NBFGR sperm cryopreservation protocols have been developed for nine species including the three Indian major carps, *L. rohita, C. mrigala, C. catla* and exotic *Cyprinus carpio*. The studies with nine species have established that the optimum requirements with respect to extender, activation media, dilution rate, activation period, sperm and egg ratio differ between species. Through modification of the cryopreservation protocols it has been possible to enhance the hatching percentage from 10% in the initial years to 77% with rohu cryopreserved milt during recent trials. Stocks of *L. rohita* milt cryopreserved in 1988 are still being maintained along with other species in a mini gene bank at NBFGR. Viable hatchlings have been produced from five year old rohu cryopreserved milt and from one year old milt of deccan mahseer, golden mahseer, common carp and rainbow trout thereby establishing the long term viability of the technique developed. The hatchlings did not exhibit any abnormality. For *C. carpio*, cryopreserved milt as a vehicle for transfer of wild genome into hatchery stocks, the cryopreservation methodology developed by NBFGR have been tested under the actual field conditions for cross breeding program. Cross breeding of farmed common carp at Bilaspur (H.P.) with cryopreserved sperms collected from wild common carp stock of Ooty and Rewalsar were carried out, for determining the population which can outperform the local stock. Results indicate that Rewalsar stock is the superior performing population. Cross breeding of slow growing rainbow trout at Nilgiris (Tamil Nadu) with fast growing stock at Barot (H.P.) through cryopreserved sperm has also been carried out. The ionic composition of seminal and variation fluid of rohu and mrigal have been studied with the objective of providing basic information that can be used to fashion new extenders and spermatozoa motility inducing media. Experience at NBFGR, clearly establishes that gene banking through sperm cryopreservation can be a viable option for long term storage of germplasm. It is possible to utilize such facilities to alleviate milt related problems, introducing genetic variability into hatchery stocks from wild and cross breeding between discrete and distant populations.

With respect to cryopreservation of embryos, cryoprotectant toxicities have been worked out in two embryonic stages of *Penaeus monodon*. Success has been achieved in getting viable larvae of *P. indicus* frozen to -40°C and of *P. monodon* that have been frozen to -30°C. The thawed *P. monodon* larvae underwent further development stages without any abnormality. With embryos of common carp and rohu, safe level of cryoprotectants have been determined and studies on vitrification and cryopreservation are in progress.

With the successful development of milt cryopreservation protocols on the one hand and successful embryo cryopreservation technique still at experimental level, it has become necessary to develop methodology for retrieval of genome from cryopreserved spermatozoa. With the chromosomal engineering technique of androgenesis, it would be possible to develop a full diploid individual from haploid spermatozoa without maternal genome contribution. Androgenetic experiments have been carried out with common carp and Indian major carps. With common carp, putative androgenetic individuals have been obtained. With cryopreserved milt of common carp also, this experiment has been successful. In the case of Indian major carps, a high variability has been observed in the sensitiveness of eggs to UV radiation used for inactivation of maternal genome and consistent results have so far not been achieved.

Future projection: With the successful development of protocols for long term cryopreservation it will be possible to upgrade the mini gene bank of NBFGR into a National facility for gene banking of fish gametes, embryos and DNA material. This will serve as a repository of wild stocks as well as improved strains. Research for expansion and improvement of gene banking technology will also be undertaken. Based on the Norwegian gene bank program for atlantic salmon, adequate samples will be collected from wild stocks of all cultivable carp species.

THREATS FACED

Aquatic resources face several stresses not only from development projects like dam construction, water diversion, pollution and physical degradation of habitat, but also from fishing and aquaculture industry itself, like destructive fishery, over harvest and selective harvest transplantations and introductions of non-endemic species and escape/ranching of farmed stocks. Though a number of papers have discussed these stresses faced by Indian fish germplasm resources, the threat due to escape/ranching of farmed stocks have not been highlighted and this aspect is covered in this paper.

Impact of hatchery stocks on wild fish: In other countries, the negative effects of escaped farmed fish on wild stocks has been felt. Studies have clearly shown that due to hatchery breeding and rearing practices, the genetic variation and life history traits of farmed fishes differ considerably from wild fish. Through biochemical genetic markers, erosion of genetic drift has been observed in hatchery stocks. Broodstocks maintained for hatchery operations are subject to artificial selection for production traits or unintended selection at the time of establishing founder stocks or during domestication. Selection for specific traits generally result in reduced genetic variance and fitness.

Due to massive introduction of cultured fish, displacement of wild stocks has been reported and high levels of introgression of the altered hatchery fish genome into wild stocks has also taken place. Escape of farmed fish and inter breeding with wild populations can result in decreased fitness of wild stocks. Release of genetically marked hatchery brown trout stock has clearly established introgression of hatchery stocks with wild stock and reduced survival of these stocks. Though outbreeding results in heterosis or hybrid vigor, if the genetic differences between two population is considerable it can result in outbreeding depression. One of the genetic mechanisms operating, is outbreeding depression which results in loss of local adaptation or breakdown of coadapted genes at different loci. Overall studies have clearly indicated that introgression of hatchery genome into wild stocks can have serious implications for long term survival of wild stocks.

In the Indian context, specific studies to show the genetic consequences of hatchery stocks on wild fish is lacking. However, studies have clearly shown that Indian hatchery stocks differ greatly from wild stocks. On screening *L. rohita* fingerlings collected from hatchery and wild, biochemical genetc differences could be observed. These results indicate that the genetic structure of hatchery stocks and wild were different. Studies on hatchery stocks of Indian major carps from Karnata State has clearly indicated that due to hatchery operations, inadvertent selection for certain traits can take place in Indian hatcheries. A decline in fertility of hatchery bred rohu has also been reported. Inbreeding in Indian hatchery stocks has also been quantified.

Genetic introgression in farmed common carp stocks of Bilaspur (H.P.) has been detected using isozyme markers. The results pinpoint the contamination of common carp broodstock with gold fish genome, which could have been due to faulty breeding practices at the farm. Using three species specific markers, it is possible to differentiate hybrids of rohu and mrigal from their parents at the fry stage. Varying percentage of introgression has been observed in different hatchery stocks of the Indian major carps. Using RFLP markers, 10% introgression was observed in one hatchery stock. Inadvertent hybridization (8.3%) of Indian major carps in Amethi hatchery due to mixed spawning has been reported.

The production and distribution of rohu hybrids called 'NATHAN' by private seed producers for aquaculture operation all over the country also adds to the risk of genetic contamination of wild stocks due to such introgressed farm stocks. Many State Governments have ongoing programs for stocking reservoirs with hatchery bred seed of Indian major carps. Also, many programs for river ranching of Indian major carps are being prepared. Studes carried out at NBFGR indicate that the level of introgression is different between hatcheries and ranching program can threaten the genetic purity and variability of wild stocks. Also, by stocking rivers with hatchery seed from broodstock originating from a different geographic area, there is danger of homogenization of natural genetic diversity. The immediate requirement is to develop a breeding strategy that can be easily applied in commercial hatcheries to avoid inadvertent selection inbreeding and introgression. Using genetic markers developed by NBFGR, it would be possible to screen out introgressed broodstock. Seed for ranching operations should be derived from wild stocks of that particular geographic area to avoid dilution of natural genetic variation.

CONCLUSION

Most of the conservation efforts are targeted at the level of ecosystem or species. Based on the genetic variation within and between populations, a species has the capacity to adopt to varying environmental conditions. Also the genetic variability within a species forms the foundation on which genetic upgradation programs can be based. Therefore, there is urgent need to fulfill the prerequisites outlined in this paper and also to take effective steps to safeguard against negative genetic consequences of escaped farmed fish.

CARP GENETIC RESOURCES IN INDONESIA

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BACKGROUND INFORMATION OF CARPS

In indonesia, where environmental condition and types of farming systems vary from region to region, the common carp *(Cyprinus carpio)* exhibits wide variation in body coloration and color pattern (markings) on the body. Dark colored morphs are represented by black, blue, grey and green, while red, orange, yellow and white are the ones with light pigmentation. Amongst them, the most common is green, and the least is white. Some well-established stocks were selected on the basis of color and given specific names, such as;"Merah" (red) which was developed by farmers in East Java, Majalaya (dull green) in West Java in 1975, "Sinyonya" (yellow) and Punten (dark green) in 1963 and 1930, respectively, by the goverment Research Institute. There are two main variations in body color pattern and markings in the common carp. The first, designated as "Domas" is characterized by white or yellow band along the cranial and dorsal body regions as well as the ventral body area. The other has scattered black patches or spots on the body and some times on the head region. However, all current pure stocks have been hybridized under farm conditions. At present, ten local names of common carp known in Indonesia refer to the color morph, body shape and scale types (Sumantadinata, 1995).

Beside color polymorphisms, the common carp stocks also exhibit differentiated gene pool that have to some extent locally adapted with different growth and morphological variability. Geographical barriers, such as rivers, mountain ranges and land breaks (island) may have split the common carp stocks of Indonesia into several sub populations among which gene flow is somewhat restricted. In research collaboration with International Development Research Centre (IDRC) during 1985 to 1990, 21 collections have been made from various isolated areas/farms.

HISTORY OF INTRODUCED SPECIES

It is still not sure whether the common carp is the oldest cultivated freshwater fish in Indonesia. However, the common carp was introduced into Indonesia from China about 150 years ago. Until about 1920, only orange colored carps were usually kept in miniature ponds in the courtyards of houses. Its culture has become an industry since the dark green European mirror carp of Galician race were brought to Java from the Netherlands in 1927, followed by the Frankish race, also from Europe, in 1930 (Schuster, 1950). The normal-scaled common carp was introduced from Taiwan in 1974 (Suseno *et al.*, 1983) and Yamato from Japan in the beginning of the year 1980.

At present, the common carp is the most important species cultured in Indonesia, having purposefully and successfully distributed throughout archipelago, especially on the island of Java. Besides Java, it has now been adopted as an economically viable species in Northern and Western provinces of Sumatra as well as in Northern Sulawesi (Hardjamulia and Suhenda, 1991). The history of transplantation of carp to Northern Sulawesi dates back to 1895, followed by others to Western and Northern Sumatra in 1903 and 1905 (Schuster, 1950). The two principal causes for increase in carp production in recent years are rapid expansion in the number of floating net cages in some newly constructed reservoirs (Costa-Pierce *et al.*, 1990; Kartamihardja, 1991) and extended paddy field areas for aquaculture (Dela Cruz, 1990).

STATUS OF WILD AND CULTURED CARP

The causes of color polymorphism in carp population can be traced to the brood stock in hatchery farms. Most breeders reared in hatcheries in Java as well as in other parts of Indonesia, are obtained from grow-out farms. Grow-out farmers prefer to culture dark colored morphs, especially green. This is correlated to their field experience that (dark) colored carps have higher fitness (e.g., better survival, larger size at maturity, faster growth rate and higher disease resistance and lower predation intensity), also dark colored carps are much preferred by consumers in comparison to other color morphs. This data is reflected in the frequency distribution of the color morphs, whereby white carps, considered the weakest in a population, are represented by the lowest proportion (Matricia, 1990; Gustiano and Phang, 1993). Consequently, hatchery operators do not have the choice of selecting the young breeders, but usually purchase all the spawners sold by established and reputable grow-out farmers. Grow-out farms depend on hatcheries for their fingerlings, so they end up with various color morphs in their stocks. In addition, consumer preferences in different regions influence selection intensity for certain color morphs. Finally, predation intensity on specific colors and natural selection for heterozygosity and varying environmental conditions may also contribute to color polymorphism in common carp.

IDENTIFICATION AND CHARACTERIZATION OF CARP POPULATIONS

Research for the identification and characterization of carp populations was initiated since long through analyzing the morphological characters (Ardiwinata, 1971). At that time, only the research institute was involved in that program, and subsequently, university followed the activity at the beginning of 1980. However, there is still no netwok forum to exchange the information among the institutions involved. The Indonesian Network on Fish Genetics Research and Development (INFIGRAD) established in 1993 became the Indonesian Chapter of INGA. The network has regular meetings and publishes a news letter in Bahasa Indonesia entitled INFOGENIK Newsletter.

At present, under the network system, the institutes are able to optimize the genetic work. In the past, research for identification and characterization of carp genetic resources was conducted by government research institute using 21 collections of common carp from various isolated areas, while the university worked on the well established stocks of common carp. In recent times, the Research Institute for Freshwater Fisheries (RIFF) and the Agency for Assesment and Applied Technology (AAAT) are involved in clarifying the variability among populations from isolated areas. Details of research undertaken in the past and the on-going research are given below:

Past research

Some studies on the carp populations were undertaken through morphologically distinguishable characters among the carps, using electrophoresis of protein and DNA analysis, Mendelian study of genetic color polymorphisms. The results of the study are:

1. Morphological and growth variability among common carp populations in different geographical areas in Indonesia (Matricia, 1990).

   In this study, the truss morphometric technique of multivariate morphometric analysis was used to distinguish morphological shape variation between common carp populations and among color morphs within populations. Multivariate statistical analysis of size and shape revealed that the 2 common carp stocks collected from Cianjur (West Java) and Payakumbuh (West Sumatra) can be classified into 2 distinct morphological groups.

2. Study on morphological variation in Indonesian common carp stocks (Sumantadinata and Taniguchi, 1990).

   Morphological studies revealed that closely related color morphs have closer distance coefficients on the dendrogram of phenetic similarity. Using 10 characters, they showed that green strains represented by Majalaya and Punten, are closely related. However, the yellow colored Sinyonya has the greatest distance coefficient to Majalaya and Punten.

3. Comparison of electrophoretic allele frequencies and genetic variability of common carp stocks from Indonesia and Japan (Sumantadinata and Taniguchi, 1990).

   Allele frequencies and genetic variability of six stocks of common carp collected from Indonesia were evaluated. Twenty-three loci were identified from 11 enzyme and protein systems. Five loci were polymorphic for the Indonesian stocks. Whithin Indonesian stocks, the phenetic relationship among the local, domas and Majalaya stocks was very close; however, the Punten, Taiwan and Sinyonya were more divergent. Based on the allele frequencies for *Pgm*, it was suggested that the characteristics of the

Indonesian common carp may reflect a mixture of common carp transplanted from China and Europe a long time ago.

4. Color polymorphisms on common carp cultured in Indonesia (Gustiano, 1993).

   Color inheritance test by single-pair intra or inter-color matings of the green, yellow and red morphs in F1 generation gave evidence that these phenotypes have the genotypes proposed by previous workers. In this study, other gene symbols for the sclae type ie., T (non-transparent) for wild type and t for transparent (Gustiano and Phang, 1994) were prepared. Two loci (R_1 and r_1, R_2 and r_2) with the additive gene effect, were probably involved in the production of yellow/red pigment, which are present in the yellow and red morphs. The dominant alleles controlled the amount of pigment produced (Gustiano, 1995).

5. Random Amplified Polymorphic DNA (RAPD) on Majalaya, Punten, Sinyonya, Merah, Kaca dan Domas strain of common carp (Aliah *et al.*, 1996).

   Priliminary results showed that the primer operon of OPA-03, OPA-09, OPA-10, OPA-13, OPA-15 and OPA-20 used in this study did not produce any polymorphic of fragment DNA. However, primer OPA-14, OPA-16, OPA-17, OPA-18 and OPA-19 revealed 19 polymorphic profiles on gel electrophoresis.

Existing research

The INFIGRAD network meeting held at RIFF, in Sukamandi in September 1996 was a recent forum for scientific exchange of the genetics reseacrh in the country. In the meeting, reports from various institutions were discussed in order to support national breeding program. The research in progress will focus on protein and DNA analysis on various stocks of common carp collected from isolated areas/farms (by RIFF and AAAT).

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CARP GENETICS RESOURCES IN THAILAND

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BACKGROUND INFORMATION ON DIFFERENT SPECIES OF CARPS IN THAILAND

Most of the scaled fish in Thailand are classified under the Family Cyprinidae which includes 4 sub-families, 55 genera and more than 200 species. They are economically important in aquaculture, freshwater capture fisheries, as well as for stocking in reservoirs. This section reviews the background information on some important native carp species in Thailand.

1. Silver barb *(Puntius gonionotus)*

Silver barb is a native carp species occuring naturally throughout the country in rivers, canals, reservoirs and swamps. It is also cultured in ponds and paddy fields. The production from capture fisheries in 1993 was estimated at 23,100 tons. Male:female ratio is 1:1.09. The length-weight relationship in fish of 5-20 cm in total length is Log W = -1.884 + 3.002 Log L, while in fish of 21-43 cm in total length, it is Log W = 1.726 + 2.909 Log L. The sizes at first maturation are 20.4 cm in females and 18 cm in males. The fish is herbivorous, feeds on blue-green algae, green algae, Euglenophytes, diatoms, characeae, aquatic and terrestrial plants, protozoans, rotifers, nematodes, cladocerans, crustaceans, insects, molluscs and fish fry. The spawning season is from May to July. The schooling behavior is found during the spawning season. The fecundity-weight relationship in females is Log F = 3.61407 + 0.89321 Log W. Females of 250 g in weight have about 371,200 eggs per fish. Eggs are non-adhesive, semi-bouyant, yellow-grayish in color and 0.6 mm in diameter. Fertilized eggs develop to 2.5 mm hatched fry within 12 hours at 25°C water temperature. Females grow 20% faster than males. Females can grow up to 500-700 g within 8-12 months in pond culture, while males can grow up to only 300 g.

2. Jullien carp *(Probarbus jullieni)*

This fish is a native carp species previously found in rivers and reservoirs throughout the country, except in the south. Over-fishing and habitat destruction by pollution caused decrease in wild populations. Male:female ratio is 1:1.59. The length-weight relationship in fish of 3-24 cm in total length is Log W = -21992 + 3.213129 Log L. In fish of 80-126 cm in total length, the length-weight relationship in females is Log W = -213566 + 3.202361 Log L, and in males is Log W = -1.16151 + 2.650352 Log L. The sizes at first maturation are 2 kg in males and 5 kg in females. The species are omnivorous, feeding mostly on molluscs. The spawning season is from December to February. The schooling behavior is found during the spawning season. Eggs are adhesive, semi-bouyant, yellow-brownish in color and 2 mm in diameter. Fertilized eggs develop to 0.9 mm hatched fry within 72 hours at 23°C water temperature.

3. Jullien's mud carp *(Cirrhinus jullieni)*

This fish is a native carp species found naturally in rivers and reservoirs throughout the country, except in the south. Male:female ratio is 1:1 male. The length-weight relationship is Log W = -5.85364 + 3.455826 Log L. This fish feeds on plankton, organic detritus, aquatic plants and insects. The spawning season is from June to September. Fish migrate upstream to spawn. The size at first maturation is 11 cm in length. The fecundity-weight and fecundity-length relationships in females are $F = 3.1021W^{0.0761}$ and $F = -1.7918L^{0.0896}$. Females of 12.9-20 cm in length have 23,550 - 90,500 eggs per fish. Eggs are semi-bouyant. Fertilized eggs develop to hatched fry within 13 hours at 26.8°C water temperature.

4. Soldier-river barb *(Cyclocheilichthys enoplos)*

This fish is a native carp species found naturally in rivers and reservoirs throughout the country, except in the south. Male:female ratio is 1:1.48. The length-weight relationship is Log W = -1.90585 + 2.9464 Log L. The size at first maturation is 34 cm in length or 435 g in weight. The species feeds mainly on molluscs. The spawning season is from May to September. The fecundity-weight relationship is Log F = 2.957 + 0.699 Log W. Females of 45-50 cm in length have 137,200 eggs per fish. Eggs are semi-bouyant, yellow-grayish in color and 1 mm in diamter. Fertilized eggs develop to 3.3 mm hatched fry within 17-19 hours at 28°C water temperature.

5. *Leptobarbus hoevenii*

This fish is a native carp species occuring in the Chao Phaya and Mekong River systems and in Boraphet reservoir. Although it is suitable for pond and cage culture, there is little local demand for this species as a food fish. It is being produced as a small fish for the ornamental trade.

6. *Catlacarpio siamensis*

The largest Cyprinid fish in Thailand and one of the largest in the world, occurs in the Chao Phaya River and some of its tributaries. Its normal size is 1-2 m in length or 70-130 kg in weight. It feeds on plankton and aquatic plants. The spawning season is from July to October. Eggs are semi-bouyant, dark brown in color and 1-2 mm in diameter. Fertilized eggs develop to hatched fry within 11-13 hours at 28-29°C water temperature.

7. *Osteochilus hasselti*

This fish is a native carp species most widely distributed in the rivers, canals, swamps and reservoirs throughout the country. Fish feeds on aquatic plants, plankton and crustaceans. Spawning season is from May to August. Brood fish of 80-200 g have 30,000-300,000 eggs per fish. Eggs are semi-bouyant and graygreenish in color. Fertilized eggs develop to hatched fry within 14-18 hours at 23-27°C water temperature.

History of Introduced Species

More than 8 species of carps were introduced to Thailand. This section reviews the history of some important introduced carp species.

1. Common carp *(Cyprinus carpio)*

Common carp was first introduced in Thailand more than 80 years back. In 1985, the Hungarian strain (P-31) was introduced from Fisheries Research Institute, Szarvas, Hungary, to Thailand. The species is found naturally throughout the country in rivers, reservoirs and swamps. It is also cultured in ponds, paddy fields and ditches. The spawning season is from January to December. Eggs are adhesive and 1-2 mm in diameter. Fertilized eggs develop to hatched fry within 48 hours at 25°C water temperature.

2. Chinese carps

Three species of Chinese carps are found in Thailand: Silver carp *(Hypophthalmichthys molitrix),* Big head carp *(Aristichthys nobilis),* Grass carp *(Ctenopharyngodon idellus).*

Chinese carps were introduced in Thailand from China more than 100 years back. They have been stocked in a number of public waters where they have become part of extensive culture fisheries. They are mostly cultured in ponds, stocked in combination with one another in the ratio of 2:1:1 for grass, silver and big head carps, respectively. The spawning season is from May to September. Eggs are semi-bouyant and 3-4.5 mm in diameter. Fertilized eggs develop to hatched fry within 18 hours at 28°C water temperature.

4. Indian carp rohu *(Labeo rohita)*

The Indian carp also known as *Rohu* was introduced from India to Thailand in 1968 and 1969. Nineteen pairs were first introduced to Thailand on November 23, 1968, and 250 fish were introduced later in 1969. The hatchery produced fish are being stocked in reservoirs and swamps in the north, northeast and central plains since 1972. The species are now found naturally in reservoirs and swamps throughout the country, except in the south. This fish is also cultured in ponds. The spawning season is from April to September. Females of 36 cm in length or 517 g in weight have 122,787 eggs per fish. Eggs are semi-bouyant, yellow-grayish in color and 1-1.4 mm in diameter. Fertilized eggs develop to hatched fry within 16-17 hours at 26-30°C water temperature.

5. Mrigal *(Cirrhinus mrigala)*

The mrigal was introduced from Bangladesh and India to Thailand in 1980 and 1982. The first 100 fish was introduced from Bangladesh to Thailand on November 28, 1980, and kept at Chiengmai Inland Fisheries Station for growth trials and breeding studies. Later in August 1982, eight pairs of brood fish of 700-800 g in weight and 500 fingerlings were brough by Dr. M.V. Gupta to Kalasin Inland Fisheries Station. The hatchery produced fish has been stocked in reservoirs and swamps in the north, northeast and central plains since 1983. It is now found naturally in reservoirs and swamps throughout the country, except in the south. This fish is also cultured in ponds. The spawning season is from April to September. Females of 1 kg in weight have 100,000 eggs per fish. Eggs are semi-bouyant and 1.5 mm in diameter. Fertilized eggs develop to 6.5 mm hatched fry within 15-20 hours at 26-28°C water temperature.

STATUS OF WILD AND CULTURED CARP GENETIC RESOURCES

Due to the restocking programs and fish stock or seed transfer, there may be genetic contamination of the natural populations from the hatchery populations in many carp species, especially in those species that can be in hatcheries produced.

CURRENT RESEARCH ON IDENTIFICATION AND CHARACTERIZATION OF CARP GENETIC RESOURCES

Institutions involved

The institutes involved in identification and characterization of carp genetic resources are:

1. National Aquaculture Genetics Research Institute (NIFI), Department of Fisheries
2. Inland Fisheries Division, Department of Fisheries

Past and existing research

1. Silver barb *(Puntius gonionotus)*

Spatial genetic structure of silver barb populations in Thailand was studied by Kamonrat (1996). Microsatellite DNA markers were developed from a Thai silver barb genomic library and used to study various aspects of the genetics of their populations in Thailand in order to provide means for evaluating management policies for the species in terms of conservation and genetic improvement. Twelve natural populations from three rivers and 29 hatchery stocks from the central and northeast regions of Thailand were studied. Genetic variability was high in both groups of populations. Multidimensional scaling analysis of genetic distances revealed the discreteness apparent between watersheds among natural populations and between geographic regions among hatchery stocks. High genetic variability within populations and significant genetic differentiation between populations both in native and hatchery stocks indicate rich genetic resources of this species in Thailand. However, there was evidence that stock management may pose a threat of losing or altering genetic integrity of both natural and hatchery populations. Mixed stock analysis of the fish sampled from the rivers indicated 75% to 96% were from hatchery populations. This high genetic contamination of the natural populations was undoubtedly the consequence of restocking programs in which millions of this species are released in rivers each year. Evidence of reduction of genetic integrity between regions was also observed in stations due to stock transfer. The results suggested an urgent need for genetically based stock management policies for both natural and hatchery populations.

Research to study the structure and genetic variation of silver barb from four Inland Fisheries Development Centers in Thailand is in progress.

2. Common carp *(Cyrpinus carpio)*

No previous research has been carried out in this species. At present, allozyme genetic data are being studied in three common carp strains.

CARP GENETICS RESOURCES IN VIETNAM

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1. BACKGROUND

Vietnam has a high potential for aquaculture development. The inland fisheries comprise 120,000 ha of small ponds and lakes and 340,000 ha of man-made lakes and reservoirs. In addition, some of the 580,000 ha of rice fields are used for fresh water aquaculture. Ministry of Fisheries estimated the total fish production in 1996 at 1.37 million tons, of which over 400,000 tons was contributed by aquaculture. Fish consumption was 15 kg/caput/year (Ministry of Fisheries 1996), contributing about 35% to total animal protein intake.

Traditional carp culture has been practised since ancient times in Vietnam. It was first promoted by the rice farmers to culture fish in rice fields and village ponds to supplement their nutritional requirement. The main cultured fish species are local common carp and other indigenous fish.

Since 1960's, with the introduction of Chinese carps (silver carp, big head carp, grass carp) together with the success of artificial propagation of these species, fresh water fish culture entered into a new era of development, as seed production was no longer dependent on nature.

In 1970's, some strains of common carp were introduced from Indonesia, Hungary and Russia. These common carp strains were used in the genetic research and selective breeding programmes in Vietnam.

In early 1980's, Indian major carps: rohu (*Labeo rohita*), mrigal (*Cirrhinus mrigala*) and catla (*Catla catla*) were introduced in Vietnam of which rohu and mrigal quickly became economically important cultured species as they are easy to breed in hatcheries and grow fast in different culture systems. Overall, the main cultured fish species are silver carp, grass carp, big head carp, Indian carps (rohu, mrigal) and local common carp forming about 90% of cultured species in fresh water aquaculture in the Northern part of the country.

2. STATUS OF WILD AND CULTURED CARP GENETIC RESOURCES

2.1. Wild carp resources[1]

Up to now, the ichthyologists described and classified 544 species of fresh

[1] The data on the wild carp resources are from the book: Fisheries Resources of Vietnam, 1997 (in press).

water fish fauna from Vietnam. These species belong to 57 Families and 228 Genera (Table 1). With two major river systems namely Red River system in the North and Mekong River system in the South, comprising many tributaries, resulted in the diversification of fresh water fish fauna in the two river systems of the country. There are only 11 species distributed in both north and south while 226 species inhabit in the north and 306 species inhabit in the south.

Table 1. Details of freshwater fish fauna of Vietnam

Sq.No.	Order	No. of families	No. of genera	No. of species
1	*Elepiformes*	2	2	2
2	*Gonorhynchiformes*	1	1	1
3	*Clupeiformes*	2	11	22
4	*Osteoglossiformes*	1	1	2
5	*Salmoniformes*	1	3	3
6	*Anguilliformes*	2	2	6
7	*Cypriniformes*	4	100	276
8	*Siluriformes*	10	31	88
9	*Cyprinidontiformes*	2	4	5
10	*Beloniformes*	2	6	11
11	*Gasterosteiformes*	1	1	1
12	*Mugiliformes*	2	3	4
13	*Sinbranochiformes*	2	3	3
14	*Ophiocephaliformes*	1	2	8
15	*Perciformes*	17	44	70
16	*Pleuronespiformes*	4	5	22
17	*Mastacembeliformes*	1	2	7
18	*Tetrodontiformes*	2	7	13
	Total	57	228	544

Cypriniformes includes 276 species belonging to 4 families and 100 genera. In particular, Cyprinidae has 228 species and sub species, of which there are many economically valuable species (Table 2). Presently, local common carp (*Cyprinus capio* L), silver barb (*Puntius gonionotus*), black carp (*Mylopharyngodon piceus*), mud carp (*Cirrhinus molitorella*) and Vietnamese silver carp (*Hypophthalmichthys harmandi*) are being commonly cultured in aquaculture systems.

Table 2: List of economically valuable carps:

Sq. No.	Local name	Scientific name
1	Ca chep	*Cyprinus carpio* L.
2	Ca lo than thap	*C. multitaeniata* (Pell & Chev.)
3	Ca day	*C. centralus* Duc & Yen
4	Ca diec	*Carassius auratus* (L.)
5	Ca nhung	*Carassioides cantonensis* (Cantor)
6	Ca danh	*Puntioplites proctozyston* (Bleeker)
7	Ca bien	*Onychostoma ovalis* Pell.&Chev.
8	Ca sinh	*O. gerlachi* (Peters)
9	Ca sinh gai	*O. laticeps* Gii:nther
10	Ca chay dat	*Spinibarbus caldwelli* (Nichol)
11	Ca bong	*Spinibarbichthys denticulatus* Oshima
12	Ca ngua bac	*Tor brevifilis* (Peters)
13	Ca cay	*Parator macracanthus* (Pell.&Chev.)
14	Ca chat trang	*Lissochilus krempfi* (Pell.&Chev.)
15	Ca coc	*Cyclocheilichthys enoplos* (Bleeker)
16	Ca ba ky	*C. repsson* (Bleeker)
17	Ca me vinh	*Puntius gonionotus* (Bleeker)
18	Ca he	*P. altus* (Gii:nther)
19	Ca duong bay	*Cosmocheilus harmandi* Sauvage
20	Ca ngua nam	*Hampala macrolepeidota* Van Hasselt
21	Ca ho	*Catlocarpio siamensis* Boulenger
22	Ca linh ban	*Thynnichthys thynnoides* (Bleeker)
23	Ca tra soc	*Probarbus jullieni* Sauvage
24	Ca chai	*Leptobarbus hoevenii* (Bleeker)
25	Ca long tong muong	*Luciosoma bleekeri* Steindachner
26	Ca tram den	*Mylopharyngodon piceus* (Rich.)
27	Ca tram co	*Ctenopharyngodon idellus* (C.&V.)
28	Ca nhong	*Luciobrama macrocephalus* (Lac.)
29	Ca mang	*Elopichphys bambusa* (Rich)
30	Ca chay mat do	*Squaliobalbus curriculus* (Rich.)
31	Ca chay trang	*Ochetobius elonratus* (Kner)
32	Ca do	*Ageneiogarra imberbis* Vineignerra
33	Ca anh vu	*Semilabeo notabilis* Peters
34	Ca me lui	*Osteochilus hasselti* (C.&V.)
35	Ca me hoi	*O. melanopleura* (Bleeker)
36	Ca ram xanh	*Altigena lemassoni* (Pell.&Chev.)
37	Ca troi	*Cirrhina molitorella* (C.&V.)
38	Ca duong	*Cirrhinus microlepis* Sauvage
39	Ca linh ong	*C. jullieni* Sauvage
40	Ca hoa	*Labeo tonkinensis* (Pell.&Chev.)
41	Ca et moi	*Morulius chrysophekadion* (Bleeker)
42	Ca linh ria	*Labiobarbus lineatus* (Sauvage)
43	Ca ven	*Megalobrama terminalis* (Rich.)
44	Ca ngao ga	*Erythroculter recurvirostris* (Sauvage)
45	Ca thieu	Culter erythropterus Basilewsky
46	Ca muong	Hemiculter lucisculus (Basilewsky)
47	Ca nhang bac	*Xenocypris argentea* Gii:nther
48	Ca me trang	*Hypophthalmichthys harmandi* Sauvage
49	Ca duc ngo	*Hemibarbus labeo* (Pallas)
50	Ca duc cham	*H. maculatus* Bleeker

2.2. Indigenous cultured fish species

Presently, 28 indigenous fish species falling under 11 families and 23 genera are being used in aquaculture systems, of which 9 species were originally native to the North, 14 species native to the South and 5 species distributing in both regions.

Popular cultured species in the North are Vietnamese silver carp, local common carp, mud carp, black carp and crusian carp (*Carassius auratus)* while in the South some species of river catfish (*Pangasius*, silver barb, sand goby and snake-head are very common in aquaculture. Out of 28 indigenous cultured species, 13 local carps are widely used in ponds and cage culture. The names of these species are in Table 3.

Table 3: List of indigenous cultured carp species

Sq.No.	Local name	Scientific name
1	Ca chep	*Cyprinus carpio* L.
2	Ca me trang	*Hypophthalmichthys harmandi* Sauvage
3	Ca troi	*Cirrhina molitorella* (C.&V.)
4	Ca tram den	*Mylopharyngodon piceus* (Rich.)
5	Ca chay mat do	*Squaliobalbus curriculus* (Rich.)
6	Ca ven	*Megalobrama terminalis* (Rich.)
7	Ca bong	*Spinibarbichthys denticulatus* Oshima
8	Ca diec	*Carassius auratus* (L.)
9	Ca me vinh	*Puntius gonionotus* Bleeker
10	Ca chai	*Leptobarbus hoeveni* Bleeker
11	Ca he	*Puntius altus* Gii:nther
12	Ca danh	*Puntioplites protozysron* (Bleeker)
13	Ca me lui	*Osteochilus hasselti* (C. & V.)

3. HISTORY OF INTRODUCED SPECIES

Since the late 1950's up to now, over 18 exotic fish species belonging 6 families were introduced in Vietnam. The details of introductions are in Table 4.

Table 4: Source and year of introduction of exotic fish species

Sq.No.	English name	Scientific name	Year introduced	Source
		Cyprinidae		
1	Silver carp	*Hypophthalmichthys molitrix* (C.&V.)	1964	China
2	Big head carp	*Aristichthys nobilis* (Rich.)	1958	China
3	Grass carp	*Ctenopharyngodon idellus* (C.&V.)	1958	China
4	Rohu	*Labeo rohita* Hamilton	1982	Laos & Thailand
5	Mrigal	*Cirrhinus mrigala* Hamilton	1984	Laos
6	Catla	*Catla catla* Hamilton	1984	Laos
7	Mirror C. carp	*Cyprinus carpio* L.	1971	Hungary
8	Scale C. carp	*Cyprinus carpio* L.	1975	Hungary
9	Indonesian C. carp	*Cyprinus carpio* L.	Before 1975	Indonesia
		Cichlidae		
10	Tilapia	*Oreochromis mossambicus* Peters	1951	Thailand
11	Tilapia	*Oreochromis niloticus* L.	1973	Taiwan
12	Tilapia (GIFT)	*Oreochromis niloticus* L.	1994	Philippines
13	Tilapia(EGYPT)	*Oreochromis niloticus* L.	1994	Philippines
14	Tilapia(Thai)	*Oreochromis niloticus* L.	1995	Thailand
15	Tilapia (Blue)	*Oreochromis aureus*	1996	Philippines
		Clariidae		
16	African catfish	*Clarias gariepinus* Burchell	1975	Africa
		Catustomidae		
17	Big mouth buffalo fish	*Ictiobus cyprinellus* Val.	1984	Cuba
		Helostomatidae		
18	Gouramy	*Helostoma temminski* (C.&V.)	1973	Southeast Asia

4. CURRENT RESEARCH ON IDENTIFICATION AND CHARACTERISATION OF CARP GENETIC RESOURCES

In Vietnam, the institutions which are involved in research on freshwater fish classification are Research Institute for Aquaculture No.1, Hanoi National University, University of Fisheries, Research Institute for Aquaculture No.2, Hue National University, Cantho University, Vinh Pedagogical Institute and some other international collaboration programmes. However, studies related to genetic identification and characterization of culture species with the goal to develop selective breeding programs, were relatively limited.

First study on intraspecific identification of Vietnamese common carp was initiated at University of Fisheries (Trong, 1965). Based on the morphometric characteristics and the colour of fish body, as well as geographical distribution, eight common carp varieties were identified including white carp, West lake carp, Baccan carp, high body carp, red carp, violet carp, mirror carp and South Haivan carp. Out of these, the most popular variety is white carp (Trong, 1983). It was recommended that some varieties should be used as initial materials for research on commercial hybridization and selective breeding programmes. Since 1981 characterization of Chinese and Vietnamese silver carp has been done (An, Thien, 1993).

Traditional wild carp seed collection from river systems was practiced by the fish farmers in north Vietnam for long. Before 1960's, Vietnamese silver carp (*Hypophthalmichthys harmandi* Sauvage)larvae were collected from Red River for nursing and rearing in ponds. In 1958, Chinese silver carp (*Hypophthalmichthys molitrix* Val.) was introduced from China. Artificial breeding and farming of these carps has been done successfully since 1963, but with little care to keep the species separately. Hence there has been much genetic mixing. Recently, it was noted that culture performance and the productive quality of marketable fish became extremely reduced (Tran Mai Thien and Phan Hong Tien 1988). A major research programme for selective breeding of silver carp was undertaken since 1981. The two main characters chosen for selecting Vietnamese silver carp were body height and number of scales on lateral line. Vietnamese silver carp has a body height of more than 30% body length (standard) (Chevey and Lemasson 1937). Where as for Chinese silver carp it is less than 30% (Wu Xian Wen et al. 1964). The scales of the Vietnamese silver carp are distinctly bigger than those of the Chinese silver carp and the number of scales in the lateral line is less than 90 for the Vietnamese and more than 100 for the Chinese silver carp. The morphological characteristics of both silver carps are presented in Table 5.

Table 5: Morphological characteristics of Vietnamese *(H. harmandi)* and Chinese silver *(H. molitrix)* carp populations.

	Vietnamese silver carp			Chinese silver carp		
Characters	Original records n=14	Generation I 1984 n=25	Generation II 1988 n=25	Generation I 1984 n=25	Generation II 1988 n=25	Generation III 1990 n=25
L (cm)	21.2 ± 0.5	31.4 ± 0.3	29.0 ± 2.9	29.8 ± 0.2	28.1 ± 0.1	14.0 ± 0.5
W (g)	385.0 ± 20.7	619.7 ± 15.5	507.4 ± 0.2	476.7 ± 7.7	380.4 ± 0.2	41.1 ± 4.7
C (%)	28.4 ± 0.8	29.7 ± 0.2	29.3 ± 0.1	27.8 ± 0.1	28.6 ± 0.1	29.0 ± 0.1
Hc (%)	28.4 ± 0.1	23.5 ± 0.1	24.8 ± 0.1	23.9 ± 0.1	24.7 ± 0.1	
H (%)	33.4 ± 0.8	32.0 ± 0.3	30.1 ± 0.3	29.0 ± 0.2	28.6 ± 0.2	27.5 ± 0.1
aD (%)	55.2 ± 0.8	50.6 ± 0.4	52.1 ± 0.3	49.5 ± 0.2	51.3 ± 0.2	50.7 ± 0.1
LP (%)	22.1 ± 0.6	21.9 ± 0.3	20.4 ± 0.3	21.0 ± 0.1	21.5 ± 0.4	21.9 ± 0.1
PV	21.9 ± 0.8	20.8 ± 0.2	18.7 ± 0.8	21.2 ± 0.4	19.9 ± 0.2	20.5 ± 0.1
LA	17.5 ± 0.9	16.3 ± 0.2	15.3 ± 0.2	15.3 ± 0.2	15.3 ± 0.3	15.0 ± 0.5
PL	13.4 ± 0.6	17.3 ± 0.2	17.4 ± 0.2	17.1 ± 0.3	18.1 ± 0.3	18.9 ± 0.1
LL (No.)	89.5 ± 3.2	87.5 ± 0.5	90.0 ± 0.8	103.6 ± 0.5	103.6 ± 0.7	

Note: *L: body length; W: body weight; C: head length; Hc: head height; H: body height; aD: antedorsal length; LP: pectoral fin length; PV: length between pectoral and pelvic fins; LA: length of anal fin base; PL: caudal penducle length; LL: number of scales in lateral line. The data given as percentages are percentages of standard length.*

Comparison of growth rate between two species indicated that the growth performance of Vietnamese and Chinese silver carp is not significantly different, but both reciprocal hybrids grew faster than their parental groups.

Investigations were continued on three year old tagged fish of the same populations with communal stocking. The experiments were carried out in three 700 m^2 ponds; stocking density: 5 fish/m^2. Table 7 summarizes the trends in growth performance. The pond environment was poor, however, the Vietnamese silver carp performed distinctly better than the Chinese silver carp. The hybrids from ♂ Vietnamese silver carp ♀ Chinese silver carp grew faster than the hybrids from ♂ Chinese silver carp x ♀ Vietnamese silver carp.

Table 6: Growth of selected group I populations of Vietnamese *(H. harmandi)* and Chinese *(H. molitrix)* silver carp populations and their reciprocal hybrids in separate ponds (31 March - 16 October 1987).

	H. harmandi	*H. molitrix*	♀ *H. harmandi* ♂ *H. molitrix*	♀ *H. molitrix* ♂ *H. harmandi*
Initial weight (g)	50.4 ± 1.3 n=19	56.3 ± 2.9 n=20	43.4 ± 1.8 n=15	80.6 ± 4.4 n=19
Final weight (g)	232.4 ± 8.0 n=34	241.5 ± 7.9 n=29	317.0 ± 6.2 n+30	373.1 ± 11.6 n=30
Increase (g)	182.0	185.2	273.6	292.5
Heterosis (% of midparent)			49.0	59.3

Table 7: Growth of selected group II Vietnamese *(H. harmandi)* and Chinese *(H. molitrix)* silver carp populations in communally stocked ponds (April-16 October 1987)

	H. harmandi	*H. molitrix*	♀ *H. harmandi* ♂ *H. molitrix*	♀ *H. molitrix* ♂ *H. harmandi*
First set:				
Initial weight (g)	230 ± 9	226 ± 11	330± 15	378 ± 14
Final weight (g)	627 ± 16	510 ± 17	716 ± 9	744 ± 18
Increase (g)	397	284	386	366
Heterosis (% of midparent			13.3	7.5
Heterosis (% of best parent)			-2.8	-7.8
Second set:				
Initial weight (g)	296 ± 10	304 ± 16	380 ± 11	432 ± 19
Final weight (g)	549 ± 10	547 ± 17	683 ± 14	695 ± 15
Increase (g)	253	243	303	263
Heterosis (% of midparent)			22.2	6.4
Heterosis (% of best parent)			19.8	4.0
Third set:				
Initial weight (g)	244 ± 7	256 ± 9	330 ± 16	402 ± 14
Final weight (g)	458 ± 9	416 ± 10	578 ± 9	630 ± 14
Increase (g)	214	160	248	228
Heterosis (% of midparent)			32.8	21.9
Heterosis (% of best parent)			15.8	6.5

Under similar conditions, the spawning season of Chinese silver carp starts earlier than that of Vietnamese silver carp by about one month. The reproductive characteristics of two species were compared in Table 8. Differences in egg quality are not clear, but Chinese silver carp is more fecund.

Table 8: Comparison of the reproductive characteristics of female Vietnamese *(H. harmandi)* and Chinese *(H. molitrix)* silver carp brood stock (April 1990)

	H. harmandi	*H. molitrix*
Number of fish examined	11	4
Average female weight (kg)	1.66	1.70
Average egg diameter (mm)	1.32	1.66
Average egg weight (mg)	1.73	1.89
Average quantity of egg spawned by one female (no.)	100,000	120,000

Since 1993, further studies on Chinese and Vietnamese silver carp stocks have been conducted to differentiate their characters. These studies focused on breeding season, physio-biological indices, karyotype and some biochemical indices. Preliminary results showed that although difference in temperature tolerance between the two silver carp species was not significant, the Chinese silver carp (*H.molitrix*) has a tendency to tolerate low water temperature better than the Vietnamese silver carp (*H.harmandi*). On the other hand, the Vietnamese silver carp has better tolerance to higher water temperature than Chinese silver carp.

A study on karyotype of these two carps showed that both species have the same diploid number of chromosomes (2n=48) and similar chromosome morphology but the karyotypes of these species are not identical: the number of metacentric and submetacentric chromosomes of the two species was a little bit different (Dung, 1992). Results of the studies on biochemical markers indicated that the two silver carp species could be identified through prealbumine and esterase in liver. The ODM, MDH and LDH in heart, blood, muscle as well as EST in heart of two silver carp species are not different (Dat, Thien, 1996). Studies on these carps are still in progress and results will be used as background materials for further selective breeding of silver carp.

KARYOTYPING OF CARP SPECIES

The research for karyotyping of 18 carps species in Vietnam was carried out by Nguyen Duong Dung (1992) and Nguyen Thi Nga (1989).

About 20-25 fingerlings from each species were karyotyped by colchicine treatment and counting chromosomes, prepared slides for study on karyotype according to the solid-tissue technique modified by Vaxiliev (1985). 353 metaphase chromosome spreads were photographed. Separate chromosomes were measured. Classification of chromosome groups was made based on the ratio between the length of long and short arms according to Levan (1964). Modal chromosome number of the studied species are shown in Table 5.

Table 9: Morphological classification of chromosomes in 18 carp species studied

Species	No. of chromosomes	No. of arms	Groups of chromosomes			
			Metacentric	Sub-metacentric	Sub-telocentric	Acrocentric
Squaliobarbus curriculus	48	78	18	12	18	
Hemiculter leuciscululs	48					
Xenocyprinis argentea	48	94	20	26	2	
Erythroculter recurvirostrix	48	86	26	12	10	
Toxabramis swinhonis	48 (1) 48	82	22 22	20 12	 14	6
Resborinus lineatus	48 (1) 48	 84	20 28	20 8	 12	8
Puntius cemifasciolatus	50					
Acanthrhodeus tonkinensis	44					
Carassius auratus	100					
Hypophthalmichthys molitrix	48 (2) 48	88 86	10 20	30 18	 10	8
Hypophthlmichthys harmandi	48	86	18	20	10	
Mylopharyngodon piceus	48	84	20	16	12	
Cirrhinus molitorella	50	86	20	16	14	
Labeo rohita	50	76	16	10	14	10
Cirrhinus mrigala	50	78	16	12	10	12
P. gonionotus	50	72	8	14	0	28
P. altus	50	82	10	22	4	14
Catla catla	50	72	8	14	14	14

(1): Trong and Dung (1990)
(2): Nga (1989)
Dung, 1992.(the rest data)

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ANNEX 2

Current Status of Carp Genetics Research and Breeding Practices in Participating Countries

CURRENT STATUS OF CARP GENETICS RESEARCH AND BREEDING PRACTICES IN BANGLADESH

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1. INTRODUCTION

Bangladesh possesses very rich and extensive inland fishery resources. The country is equally rich in its fish genetic resources, with about 260 freshwater fish species, of these, 25-30 species are important for aquaculture. In recent years, inland fisheries is under heavy pressure due to deterioration of environmental conditions; siltation and soil erosion on river basins; water pollution from industrial, agricultural and municipal wastes; construction of embankments for flood protection; injudicious and destructive fishing practices; outbreak of diseases etc. and loss of natural fish breeding grounds as a result of habitat alteration. As a result, the overall production and supply of fish is declining rapidly. Present situation might lead to decline in per capita consumption of fish and animal protein in Bangladesh.

Despite the possibility of sustainable increase, fish production from open water bodies is limited; the major increase in fish supply has to come from aquaculture of fresh, brackish and marine water fishes. No doubt, Bangladesh has tremendous scope to develop aquaculture technologies. For improving the nutrition of the protein hungry people, for increasing income of rural households and national economy, the need for increased and appropriate research in fish breeding and farming practices, especially for the important commercial species available in the country, was felt.

Therefore, in recent years, breeding and genetic stock improvement of commercially important fishes, particularly carps was identified as an important area of research to make a major contribution in increasing productivity and profitability from aquaculture. In view of this, research for genetic stock improvement in carps was initiated in 1986. This report presents briefly the ongoing carp genetics research and planned activities in Bangladesh.

2. INSTITUTE(S) INVOLVED IN CARP GENETICS AND BREEDING RESEARCH

The carp genetics and breeding research is being undertaken at the Freshwater Station (FS) of Bangladesh Fisheries Research Institute since the inception of the Institute in 1985. The FS, with an area of 40 ha, is situated at the south-west corner of the Bangladesh Agricultural University, Mymensingh which is some 120 km north of the capital city, Dhaka at Latitude 24°C 46' N and Longitude 90° 24' E. The FS has as many as 118 drainable ponds including a nursery complex with ponds ranging in size from 0.04 to 0.62 ha each. In addition, there is a well equipped hatchery complex including a large number of cemented cisterns and holding tanks.

3. CURRENT STATUS OF CARP GENETICS RESEARCH

Research Activities (1986-92)

3.1 Induction of meiotic gynogenesis in rohu (Labeo rohita) and mrigal (Cirrhinus mrigala)

Meiotic gynogenesis was induced by giving heat shock to eggs fertilized with irradiated sperm. Sperm was irradiated with a constant dose of UV rays for 2 minutes from a distance of 13.5 cm. In rohu, 4 minutes after fertilization, when heat shock was applied at 40°C for 2 minutes, gynogenesis was induced in 80 to 90% cases. Similar heat shock regime was found optimum for mrigal. A temperature of 39°C was more effective and gynogenesis was 80 to 100%. Survival in both species was low (2 to 40%) compared to that of normal control (30 to 60%).

3.2 Understanding the sex determining mechanism in rohu and mrigal

Gynogenetic rohu and mrigal were reared in ponds. Seventeen out of 24 rohu and 60 out of 264 mrigal, survived till second year. Sex ratios (♀:♂)for rohu and mrigal were 7.5:1 and 14:1 respectively, indicating that the females in both species are homogametic. The presence of a very low number of males probably indicates an error somewhere in the procedure.

3.3 Sex reversal of gynogenetic mrigal

The study was conducted for the hormonal sex reversal of the gynogenetic hatchlings of mrigal. The experiment was aimed at production of sex-reversal male of the intended gynogenetic female hatchlings of mrigal to be used in hybridization with the gynogenetic female rohu.

A synthetic androgen hormone, 17a-methyletestosterone was orally administered to the intended gynogenetic female hatchlings of mrigal at 150 to 200 mg/kg of feed for 3 months. Survival up to their third year of life was 48%. The average weight of those fishes was 1.5 kg during the period of sex differentiation. The sex ratio (♀:♂) was found to be 5.5:1. From the sex ratio of the treated fish, it was concluded that the hormone doses used were ineffective in reversing the sex of gynogenetic mrigal.

3.4 Production of heterotic hybrids by crossing meiotic gynogenetic lines of rohu and mrigal

In order to produce heterotic hybrids by crossing with the gynogenetics, 4 crosses between gynogenetic female rohu and normal mrigal male, and 14 crosses between gynogenetic mrigal female and normal rohu male, were made.

Observation on the comparative growth performance of the hatchlings produced as a result of crosses between gynogenetic females and normal males of rohu and mrigal showed that hatchlings produced from 3 crosses out of 10 resulted in better growth in comparison to the normal control. In 7 crosses, the growth was more or less similar or lower. In a separate experiment, the hatchlings of 3 crosses, which showed better growth performance during 1 month rearing period were allowed to grow for another three months. The growth of the test hybrids was found much higher than that of normal control and there was significant difference ($P<0.05$) between the growth of the test hybrids and that of control (normal rohu and mrigal).

Research Activities (1993-97)

3.5 Breeding plans for stock improvement of catla (Catla catla)

Breeding and genetic improvement programme has been initiated in major carps, particularly in catla, *Catla catla*.

In view of this, land races of *C. catla* were collected in 1994 from different river systems of the country viz., Halda, Jamuna and Brahmaputra. These wild stocks are being screened by investigating differences in intrinsic and extrinsic genetic traits by means of electrophoresis, morphological and growth assessment. All these land races are being reared in Freshwater Station (FS), FRI, Mymensingh and expected to be sexually mature in 1997 or 1998. On the basis of their gonadal and other related performances, two or more lines will be established through conventional methods by unrelated crossing. With all these lines, selective breeding and line crossing programme will be continued, which will result in the development of genetically improved strain having better culturable traits.

3.6 Induction of mitotic gynogenesis and production of genetic clones in rohu

Induction of mitotic gynogenesis to produce clonal line in rohu, had been initiated during 1993/1994 at the FS, FRI, Mymensingh. Efforts were made to interfere with the normal functioning of spindle apparatus during mitotic cell division of fertilised eggs using heat shock treatment, thereby leading to the induction of mitotic gynogenesis in F_1 generation (Table 1). Afterwards, putative mitotic gynogenetic alevins were reared as broodstock and a sexually mature female was used to obtain ovulated eggs which were fertilized later with UV irradiated milt. The UV irradiation was carried out for 2 minutes at an intensity of 200 to 250 mW cm^{-2} at 28°C. Optimal heat shock of 40°C for 2 minutes was applied 5 minutes after fertilization to produce clones through meiotic gynogenesis in the F_2 generation (Table 2). It is expected that these clonal lines could successfully be used in breeding programmes to improve stock performance within a short period of time, compared to many generations of breeding required for normal genetic selection.

3.7 *Stock improvement of Silver barb (Puntius gonionotus)*

A. Selective breeding and line crossing

For genetic stock improvement of silver barb through selective breeding and line crossing technique, two separate lines were maintained involving two wild stocks (germplasm) obtained through ICLARM from Thailand and Indonesia in 1994. These two unrelated stocks and existing local stock in Bangladesh were reared in three earthen ponds separately. During the first year, they were mated themselves under normal breeding programme to produce F_1 generation. During spawning season of 1996 all F_1 generations (Thai x Thai; Indo x Indo and Bangla x Bangla) were crossed following 3 x 3 diallele crossing design as shown in Table 3 to form a heterogeneous, outbred base population for the breeding programme.

(i) Evaluation of growth performance of progenies derived from diallele crosses

Six different hybrid and three control progeny groups derived from diallele crosses were stocked communally (having equal number of representative fish from each of the group) in same pond using AVID tags. A total of six ponds were selected on the basis of their over all conditions like productivity, depth and other physical features and divided into "Good", "Medium" and "Poor" ponds. Each of the test environments had two replicate ponds having same stocking density. Growth performance of individual progeny group was evaluated until their maturity and harvesting (June/July'97). Preliminary results of this experiment are in Table 4.

(ii) Development of outbred broodstock

For each of the six reciprocal crosses, 3 to 4 pairs (ratio of female to male 1:1) were mated separately, producing at least 18 full sib families. All matings were done within one - two days. The fertilized eggs were incubated in a series of funnel jars and hatchlings were kept in a series of hapas until first feeding stage. As nursing of the sib groups in separate hapas was not possible and due to limitation of individual nursery ponds, 125 larvae were counted from each of the 18 progeny groups (from each sib group) and communally stocked at least in two nursery ponds (400 m^2 meter each). Subsequently, they will be transferred to communal rearing ponds and later on to grow-out ponds (Figure 1). During all the phases of rearing period, they will be given protein rich supplementary feed and at the age of 11 - 12 months, a large number of breeders will be available for the proposed selection programme.

B. Production of all female population

Recently, a collaborative programme was initiated with the University of Stirling, Scotland, UK to produce all female *P. gonionotus* using the technique of gynogenesis and sex-reversal. The rationale of this programme is to generate all female population which has better growth rate than males, for use in aquaculture. If the monosex female technique is to be used in conjunction with the selective breeding of Thailand, Indonesian and existing Bangladesh stocks, it is essential to know whether the sex determination mechanism in these stocks are the same.

In view of this, during April 1996 eight putative neomale fish (produced at NAGRI, Bangkok) were transported from Thailand to Bangladesh. Before transportation, they were examined at AAHRI, Bangkok, treated with formalin and given a health certificate. Two experiments as detailed below were conducted using neomales.

(i) Crosses between putative neomales and Thailand originated females

In this study, three groups of fish were produced; i) crosses between putative neomales and Thai origin females, without hormone treatment; ii) crosses between putative neomales and Thai origin females, treated with androgen hormone; iii) control crosses between Thai origin males and Thai origin females. The objectives are to give information on sex ratios of putative neomale offspring and produce more neomales from sex-reversal of fry in broods where untreated fry are all female.

Sex ratios from these crosses are in Table 5. The data on the non-hormone-treated putative neomales is compatible with that from Thailand: Neo-2-4 and Neo-2-6 are confirmed as neomales (giving very close to all-female offspring), while Neo-2-2 gave a sex ratio not significantly different from 1:1, suggesting that it is a normal male. Hormonal masculinization has worked reasonably well in case of the offspring of Neo-2-4 and Neo-2-6 (mean 20.5% males), while the hormone treated offspring of 2-2 actually had a lower percentage of males than the untreated group.

(ii) Crosses between putative neomales and Indonesian origin males

Two groups of fish were produced; i) crosses between putative neomales and Indonesian origin females, without hormone treatment; ii) control crosses between Thai origin males and Indonesian origin females. The aim of this trial is to obtain information on compatibility of sex determination mechanism in these two isolated stocks of silver barb.

Three putative neomales (Neo-2-1, Neo-2-2 and Neo-2-3) were crossed to Indonesian origin females, along with a single Indo x Indo. The control gave 60 males and 59 females (50.4% males; $X^2 = 0.01$ n.s.) while the three neomales gave sex ratios of 56 males and 33 females (62.9% males; $X^2 = 5.94$ $p<0.05$), 54 males and 38 females (58.7% males; $X^2 = 2.78$ n.s.) and 73 males and 39 females (65.2% males; $X^2 = 10.32$ $p<0.01$), respectively. While 2-2 and 2-3 gave sex ratios of 68.6% males and 51.9% males in progeny testing done in Thailand (the first of these was significantly different from 1:1), male 2-1 gave a sex ratio of 2.7% males in a cross to a Thai female (Nakhon Phanom). These results may indicate some disruption of sex determining system in crosses between the Thai and Indonesian groups, but the possibility needs further investigation.

4. CONSERVATION OF THREATENED CARP SPECIES

Owing to consequences of natural and man induced phenomena occurring in aquatic ecosystems, the natural breeding grounds of some of the important floodplain and riverine fish and their habitats have been severely disturbed. These have endangered the carp genetic resources in Bangladesh. There is a need, therefore, to develop artificial breeding techniques of threatened carp species for conservation of their "gene pool". In view of this, attempt was made at FS, FRI, Mymensingh to develop artificial breeding techniques of *Tor* spp. and *P. sarana.*

(i) Development of artificial seed production technique of mahseer, Tor spp.

Tor spp. popularly known as mahseer are the important group of freshwater fishes of Bangladesh. They are primarily inhabitants of hill streams and tributaries and canals; and have wide distribution in Bangladesh, India, Nepal and Pakistan. There are two species viz. *T. tor* and *T. putitora* available in Bangladesh. Presently, the wild stocks of mahseer are in danger of extinction. While *T. tor* is some times available in Netrokona and Sylhet areas of Bangladesh, *T. putitora* is rarely to be found in recent days. Therefore, about one thousand fingerlings (size 5 cm) of *T. putitora* were brought to Bangladesh from Nepal in January 1991. The fish were reared in earthen ponds (0.1 ha) at stocking density of 2000 fish/ha. The ponds were flushed twice a week with fresh underground water and the fish were fed with supplemental feeds (25% crude protein). All males and most of the females attained sexual maturation within two years while some of the females took three years to mature. During November 1993, four females (550-9000 g each) of separate batches bred successfully through manual stripping without any hormone injection. The number of eggs obtained per female varied from 7292 to 11667. The rate of fertilization, hatching and survival at yolk sac resorption stage were about 90, 70 and 53% respectively (Table 6). Hatching time was about 67 hours and yolk sac was absorbed within 10 days. Boiled eggs was used as larval feed for two days before stocking the hatchlings in nursery ponds (Mahata *et al.*, 1995).

(ii) Development of induced breeding technique of silver barb, P. sarana.

A total of 45 female *P. sarana* (weighing 90-300 g each) were induced to breed by injecting a single dose of 5.0 to 8.0 mg PG/Kg body weight and the male fishes (weighing 80-185 g each) with a dose of 4 mg PG/kg body weight. Ovulation occurred in all the injected females. Fish spawned naturally in the spawning hapas placed in concrete cisterns after 6-7½ hours at an ambient water temperature of 25 to 29°C.

5. CARP CULTURE AND BREEDING IMPROVEMENT AND CONSTRAINTS RELATED TO GENETICS

It is well established fact that, in genetically closed systems, potential selective pressures exerted on finite and often closely related populations by various management practices result in "indirect" or "negative" selection of important life history traits, therefore, leading to inbreeding and genetic drift. In such case, a careful designing of management practices to control this is essential to maximize the genetic potential of the culture stocks (Doyle, 1983; Gall, 1983). While this need to be attempted, careful screening of the different land races of carps from different river systems is essential to evaluate their desirable culture traits. In Bangladesh, seed of major carps have been produced since 1967 mainly through induced breeding. Beside the government hatcheries, a large number of private hatcheries, estimated over 400, have been established in different parts of the country. These hatcheries are presently contributing nearly about 90.2% of the total spawn production and other 9.8% coming from natural sources mainly from rivers (Hussain and Mazid, 1995). In recent years, reduction in growth and reproduction performances, increased incidence of morphological deformities, disease and mortalities have been reported from hatchery populations. Though no systematic investigation has been carried out to understand the cuasative factors in aquaculture stocks, it is generally believed to be due to i) unconscious negative selection of broodstock; ii) mating of female and male spawners from a finite population and iii) unplanned hybridization in hatchery stocks (mainly carps).

Poor broodstock management and close mating of breeders (possibly sib cross and parent vs. offspring cross) result in inbreeding leaving adverse effect on aquaculture production as well as on open water fisheries in view of stocking of hatchery bred seed in floodplains and other open water bodies.

6. FUTURE RESEARCH NEEDS

a. Characterization and gene mapping of land races of major and minor carps;

b. Development of outbred broodstock for most of the commercially important carp species to ensure quality seed production for aquaculture;

c. Genetic stock improvement of farmed fish (carps and other species) using conventional, genome manipulation and molecular techniques;

d. Estimating inbreeding rate in hatchery stocks (mainly carps);

e. Development of breeding technique for seed production of threatened or endangered carp species;

f. Conducting a thorough survey of endemic carp genetic resources;

7. REFERENCES

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Table 1: Observations on the production of mitotic gynogenetics in rohu, *L. rohita* Ham.

Sl. No.		Normal Control	Haploid Control	Meiotic Gynogens	Mitotic Gynogens
1.	Fertilization (%)	85	85	87	80
	Hatching (%)	46	02	05	07
	Viability at one week age (%)	37	0	3.4	4.8
2.	Fertilization (%)	100	97	97	90
	Hatching (%)	92	0.9	2.5	3.7
	Viability at one week age (%)	35	0	1.67	2.5
3.	Fertilization (%)	82	38	26	30
	Hatching (%)	58	1.5	03	03
	Viability at one week age (%)	16	0.003	0.004	0.003
4.	Fertilization (%)	95	40	30	25
	Hatching (%)	70	1.2	3.3	2.2
	Viability at one week age (%)	33	0.06	0.26	0.25

Table 2: Observation on the production of F_2 'Clone' through meiotic gynogenesis using F_1 brood from mitotic gynogens of rohu, *Labeo rohita*.

Sl. No.	Observation	Normal control (%)	Heploid control: UV=200 mW cm^{-2} (%)	Heploid control: UV=250 mW cm^{-2} (%)	Meiotic Gynogens i.e., clone (%)
1.	Fertilization	98	76	-	68
	Hatching	92	0	-	5
	Survival at one week age	84	0	-	66
2.	Fertilization	87	62	-	64
	Hatching	82	2	-	2
	Survival at one week age	84	89	-	66
3.	Fertilization	98	-	72	74
	Hatching	92	-	0	12
	Survival at one week age	84	-	0	66
4.	Fertilization	87	-	67	62
	Hatching	82	-	0	2
	Survival at one week age	84	-	0	66

Table 3: Diallel crossing pattern of *Puntius gonionotus*.

	T	I	B
T	-	TI	TB
I	IT	-	IB
			-

Table 4: Performance of 9 hybrids

Sl. No.	Group Name	Initial size		Final size		Sex ratio	Growth rate (%)	
		♀	♂	♀	♂	♀ ♂	♀	♂
1.	B X B	33.99	28.73	258.13	138.26	16 : 23	659.43	381.24
		±6.37	±7.27	±49.83	±24.06			
2.	T X T	26.73	26.87	253.00	128.41	20 : 27	846.50	377.89
		±3.66	±4.85	±56.18	±27.40			
3.	I X I	37.02	35.91	212.33	133.81	15 : 21	473.55	272.63
		±5.24	±6.00	±31.84	±27.97			
4.	B♀ X T♂	33.37	31.99	238.21	125.68	14 : 22	613.84	292.87
		±6.39	±5.59	±44.88	±24.02			
5.	T♀ X B♂	18.21	16.85	246.88	130.68	16 : 22	1255.74	675.55
		±3.69	±5.89	±39.41	±25.51			
6.	T♀ X I♂	25.15	23.19	248.85	138.70	26 : 23	889.46	498.10
		±6.20	±6.06	±46.55	±17.34			
7.	I♀ X T♂	23.76	24.11	224.00	128.61	21 : 28	842.76	433.43
		±4.88	±4.72	±37.40	±29.36			
8.	B♀ X I♂	30.41	29.06	264.74	134.78	20 : 22	770.57	363.80
		±3.87	±3.31	±40.81	±19.04			
9.	I♀ X B♂	30.40	27.63	262.00	122.52	10 : 31	761.84	343.43
		±5.40	±6.24	±53.03	±18.76			

Table 5: Sex ratios in offspring of putative neomales and control Thai origin males crossed to Thai origin females M=no. of males, ?=no. of undifferentiated fish (no visible gonad of PIT-tagged as not clearly male of female); F=no. of females; %M= percentage of males.

Male	Treatment							
	None				MT			
	M	?	F	%M	M	?	F	%M
Neo-2-2	64	0	66	49.2	36	0	56	39.1
Neo-2-4	1	0	47	2.1	36	0	84	11.5
Neo-2-6	1	0	33	2.9	23	3	52	29.5
Thai Cont. 1	60	0	67	47.2	-	-	-	-
Thai Cont. 2	63	0	50	54.8	-	-	-	-

Table 6: Details of induced breeding of *Tor putitora*

Date	Size of spawner		No. of eggs obtained	Fertilization	Hatching	Deformity	Survival
	Male	Female					
18.11.93	300 g (37 cm)	900 g (47 cm)	7,292	92.33	69	20	53.97
		700 g (43 cm)	7,320	93.00	68	24	53.00
24.11.93	350 g (35 cm)	700 g (42 cm)	7,300	93.33	70	18	50.00
25.12.93	350 g (34 cm)	550 g (42 cm)	8,000	93.00	75	16	54.00
04.01.94	300 g	900 g (46 cm)	11,667		All eggs damaged		

CURRENT STATUS OF CARP GENETICS RESEARCH AND BREEDING PRACTICES IN CHINA

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1. INTRODUCTION

China is rich in aquatic resources. Just as there are many aquatic species, so are the multiplicity of common carp (*Cyprinus carpio)* strains, both in form and in genetic characters.

There are many hypotheses regarding the origin of common carp and the classification. According to Gunther (1968), carp species originated in temperate region, especially in China. Okade (1985) considered that carp species are from Middle-Asia, and were introduced into China, Japan, Greece, and then into Europe via Italy. Jhingran and Pulin (1985) gave the zone of natural distribution of common carp as 35 ° to 50° North latitude, 30° to 135° East longitude and areas less than 300 meters above sea level. Regardless of the hypotheses mentioned above, China has a long history of at least 2400 years, of culturing common carp. Ancient literature summarized the experiences of common carp farming in China dating back to 5 B.C. Common carp is a favorite fin-fish throughout China.

The species has a wide distribution and strong adaptability. There are many morphological variations through artificial breeding and natural selection of this species, (e.g., scattered mirron carp, mirror carp, *Cyprinus carpio wuyuanensis, C. c. singuonensis,* Jian carp, etc.).

2. INSTITUTIONS INVOLVED IN CARP GENETICS AND BREEDING RESEARCH

- Freshwater Fisheries Research Institute, Chinese Academy of Fisheries Sciences, Wuxi, Jiangsu, 214081
- Changjiang Fisheries Research Institute, Chinese Academy of Fisheries Sciences, Shashi
- Heilongjiang Fishery Research Institute, Chinese Academy of Fisheries Sciences, Harbin
- Institute of Developmental Biology, Academia Sinica, Beijing
- Institute of Hydrobiology, Academia Sinica, Wuchang
- Shanghai University of Fisheries, Shanghai,
- Jiangxi University, Nanchang,
- Normal University of Hunan
- Department of Biology, Yunnan University, Kuiming
- Institute of Fisheries research of Hunan

3. CURRENT STATUS OF CARP GENETICS RESEARCH

3.1 Research achievements

3.1.1 Cross breeding

To date, cross breeding has been tried among many fish species, but most of the trials have failed to give any positive results. Over 100 crosses have been tried in species of Family Cyprinidae. The few hybrid progenies with good characters are listed as follows:

- Fong carp — *Cyprinus carpio var. singuonensis* x Scattered mirror carp,
- Heyuan carp — *C. carpio var. wuyuanensis* x *C. carpio var. yuankiang,*
- Yue carp — *C. carpio var. wuyuanensis* x *C. carpio* (from Xiang river)
- Baiyuan carp — *C. carpio var. yuankiang* x *C. pellegrini,*
- Tri-crossed carp — [(*C. carpio* var. *wuyuanensis* x *C. carpio* var. *yuankiang*) x mirror carp],
- Backcross carp — [*C. carpio* var. *yuankiang* x (*C. carpio* var. *wuyuanensis* x *C. carpio* var. *yuankiang*)].

All the hybrids mentioned above possess economically important characters (such as higher growth rate, better feed conversion rate, higher fishing rate, etc.), and hence, have become main cultured freshwater fish throughout China.

3.1.2 Haploid breeding

Artificially introduced gynogenesis and androgenesis was initiated in China in 1970s.

Artificial gynogenesis has been successfully tried in more than 20 species. Chinese scientists improved the technique and utilized it in goldfish (*Carassius auratus)*, red variety of *C. auratus, Cyprinus carpio var. singuonensis,* grass carp (*Ctenopharyngodon idellus*), silver carp (*Hypophthalmichthys molitrix*), and others. A good example is allogynogenetic crucian carp, that is a result of female progeny from gynogenesis of Fangzheng crucian carp (a variety of *Carassius auratus gibelio,* a natural triploid) crossed with male *Cyprinus carpio singuonensis.* This is listed by farmers because of its higher growth rate.

Occasionally, androgenesis is used in distant hybridization. Stanley reported (1979) that an individual from androgenesis was achieved in the crossing of mirror carp with grass carp. In 1987 Liu and his colleagues utilized mechanical method to get rid of oriental weatherfish gynokaryon of intergeneric crossing between oriental weatherfish (*Misgurnus anguillicaudatus*) x *Paramisgurnus dabryanus*, and to get a haploid embryo from androgenesis. When the embryo developed to blastula stage, blastula karyon was transplanted into the egg (got rid of nucleus in advance) of *Paramisgurnus dabryanus*. In this way, five tails of pure diploidy animals from androgenesis were obtained.

3.1.3 Polyploid Breeding

Generally, it is believed that polyploid fish has a higher growth rate and stronger adaptability than that of diploid. For this reason, the techniques of introducing polyploid have been becoming the focus of breeders.

In China, artificially induced triploid and tetraploid fish were produced in over 10 species. They are:

- grass carp (*Ctenopharyngodon idellus*),
- silver carp (*Hypophthalmichthys molitrix*),
- bluntnose black bream (*Megalobrama amblycephala*),
- rainbow trout ,
- common carp *(Cyprinus carpio* var. *wuyuanensis),*
- hybrid between *C. carpio* var. *singuonensis* x grass carp,
- hybrid between *Cyprinus carpio* var. *wuyuanensis* x *Carassius auratus cuvieri,*
- hybrid between grass carp x black bream (*Megalobrama terminalis*),
- hybrid between *Carassius auratus cuvieri* x red goldfish (*Carassius auratus* ,red strain).

Among them, the triploid of hybrid between *Cyprinus carpio* var. *wuyuanensis* x *Carassius auratus cuvieri*, possesses commercial value

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3.1.4 Sexual control

The sexual differentiation of fish, in some species, influence its growth rate and other economical characters, for example, the growth rate of male tilapia is higher than that of female, on the contrary, female common carp and grass carp grow faster than male. In order to control the sexes of fish, methods such as interspecific crossing, introduction of sex reversal, production of super-male-fish, are available. In China, these techniques have been successfully used in tilapia.

3.1.5 Mutation breeding

It is very common techniques using mutagens, both chemical and physical, to obtain mutants. Since 1970's, γ-ray and quick-neutron have been tried to irradiate the gonad, embryo, fry and fingerling of common carp, grass carp, tilapia, in order to find mutant. Unfortunately, no effective results have been obtained.

3.1.6 Integration breeding

The breeding practices revealed that it was useful to combine two or more breeding techniques together to get new varieties or strains. *C. carpio* var. *jian* is a good example of integration breeding because of its stable genetic characters with commercial value and nice appearance. Up to date, the new variety has been extended to 25 provinces, municipalities and autonomous regions. The integration breeding techniques combine family selection, inter-family crossing with gynogenesis.

3.1.7 Utilization of germplasm resources

There are about 100 species of fish for aquaculture throughout the world. Among them, most species are not indigenous to the countries and introduced from other countries or regions. The following species were introduced into China:

- Russian scale carp,
- Scattered mirror carp,
- Germany mirror carp,
- Rainbow trout (*Salmo gairdneri*), 1959 (Hailongjiang)
- Donaldson's super rainbow trout, 1983, from Washington University, USA,
- White crucian carp (*Carassius auratus cuvieri*), 1959 (Taiwan), 1973 (Hong Kong), 1976 (Guangdong)
- Mozambique tilapia (*Oreochromis mossambicus*), 1945 (Taiwan), 1956 (Guangdong)
- Nile tilapia (O. *niloticus*), 1966 (Taiwan),1978 (Hubei),
- Blue tilapia (*O. aureus*), 1981 (Guangdong and Jiangsu),
- Walking catfish (*Clarias batrachus*),
- *Labeo rohita*, 1978 (Guangdong),
- *Colossoma brachypomum*, 1982 (Taiwan), 1985 (Guangdong)
- Channel catfish (*Ictalurus punctatus*), 1984 (Hubei),
- Large mouth bass (*Micropterus salmoides*), 1984 (Guangdong).

Subsequent to their introductions, they have become main cultured fish throughout China.

In addition to the applied research, basic theory studies have been done by some academic institutes and universities. These projects deal with wide aspects including 1)the determination of isoenzyme; 2) analysis and comparison between the karyotypes of *Cyprinus carpio* and *Carassius auratus*; 3) investigation on the carp gynogenesis; 4) construction of the genomic libraries of primarily cultured freshwater fish; 5) preliminary study on the specificity of red blood cell antigens in various varieties (strains) of carp, and others.

3.2 Research prospects

Studies on the breeding of fish are progressing rapidly in China. The methods and techniques commonly used worldwide have been tried and improved, in some fields of fish breeding. Priorities for future research in carp breeding and genetic research are as below.

3.2.1 Transplant of karyon and cell culture

In 1970's, Tong Di zhou and Yan Sao yi have undertaken the basic research for transplant of karyon and cell culture, and utilized the technique and method in economically important fish. In this way, they and their colleagues successfully achieved nuclear-cytoplasmic hybrid fishes, such as common carp x crucian carp (CyCa), crucian carp x common carp (CaCy), grass carp x bluntnose black bream, and tilapia x common carp and others. CyCa has completed third generation.

In order to find out if any changes are induced at genome level after *C. carpio* nuclei have been transplanted into *C. auratus* cytoplasm, their DNA ressociation kinetics has been studied. It was found that the nuclear-cytoplasmic hybrid fish (CyCa) F_3 is the same as C. carpio. Nuclear genome is not affected by heterologous cytoplasm in nuclear transplant process.

Cell culture of fish started as early as 1914. For chromosome studies, the techniques of cell culture have been advanced since 1970's. The cells from different tissues and organs, like blood cell, fin cell, scale cell, cardiac muscle cell, nephric cell and others, have been cultured in laboratories. These techniques possess practical value, and can be used in nuclear transplant.

3.2.2. Cell fusion

The study on cell fusion has a long history. Since 1980's, a new technique, electric fusion, has been adopted in fish cell fusion. But the experimental species used was *Paramisgurnus dabryanus* which has low commercial value. Hence, our goal is to transfer the technique to economically important fish. On the other hand, new techniques for fish cell fusion are urgently required, and it is planned to use laser to improve cell fusion.

3.2.3 Genetic engineering

The new technique has been adopted in China since 1980's, for example, the isolation of antifreeze gene from fish and the cloning of antifreeze protein gene cDNA of fish and its expression in E. coli, as well as the insertion and recombination of growth hormone gene.

4. CARP CULTURE AND ITS BREEDING

In China, common carp is not only a favorite cultured species, but also a species fished from natural waters, and accounts for 30% of total volume. In northern part of China, common carp accounts for 60% from culture in ponds, cages, and in reservoirs. In southern China, the quantity is about 20% among all cultured species.

China has been continuing the culture and genetic improvement programs. Cross breeding and integration breeding have proved practicable in finding excellent varieties or strains. For example, *Cyprinus carpio* var. *jian* is a new variety, that is a result of integration breeding as mentioned before.

The extended varieties and hybrids of common carp in China are as following:

- *Cyprinus carpio singguonensis*
  (1) Breeding institute and agency : Red Carp Reproduction Farm of Singuo County and Biological Department, Jiangxi University.

(2) Background : More than 130 years ago, the variety was cultured in Singuo county. Since 1972, the native variety has been used for selective breeding. After six generations selection, there is 10% gain in growth rate. Red individuals in population accounts for 86.6%. The stability in apparent form reached 98.6%. The variety was identified by Fisheries Bureau in 1985.

(3) Total productivity : about 5000 tons annually.

(4) Others : It is the parent of several hybrids like, Fong carp, Lotus carp, and allogynogenetic crucian carp.

- *Cyprinus carpio wuyuanensis* (CCW)

(1) Breeding institute and agency : CCW Research Institute of Wuyuan County, and Biological Department, Jiangxi University, and the Institute of Hydrobiology

(2) Background : The variety has been cultured in Wuyuan County for over 300 years. Since 1961, its biology has been studied by Institute of Hydrobiology, Academia Sinica and CCW Research Institute of Wuyuan County. After six generations' selection, its characters tend to be stable, the red individual is 89.54%.

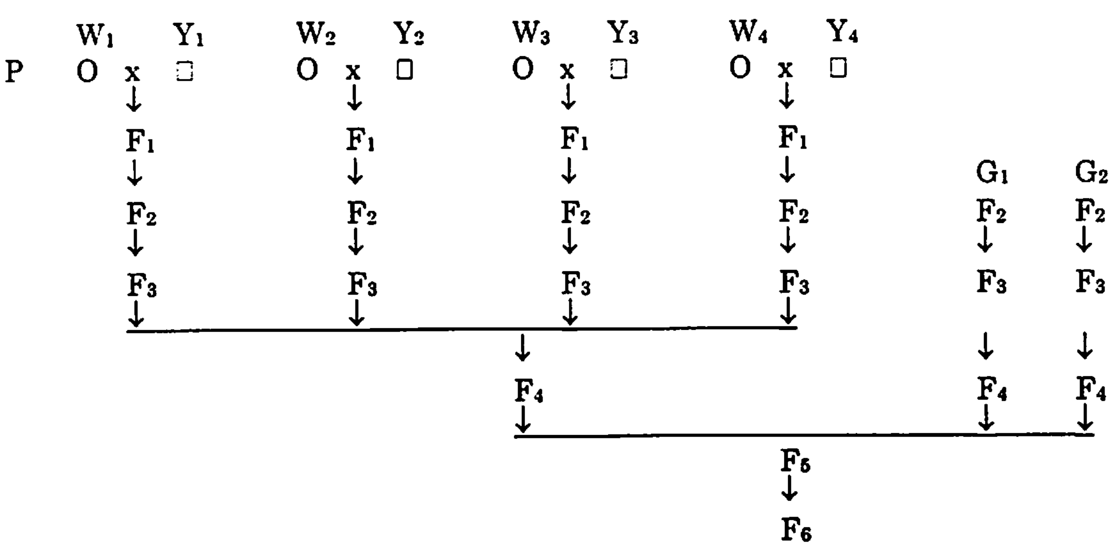
(3) Total productivity : about 5000 tons annually.

(4) Others : The variety is the parent of other varieties and hybrids, like Heyuan carp, Yue carp, Tri-back hybrid, and Jian carp.

- *Cyprinus carpio var. jian*

(1) Breeding institute and agency : Freshwater Fisheries Research Institute.

(2) Background : Its parents are *Cyprinus carpio wuyuanensis* and *C. carpio yuankiang*. It is a result of integration breeding including family selection, inter-line cross combining with gynogenesis (fig. 1). The genetic stability is over 95%



Where W_1 to W_4 is female *C. carpio wuyuanensis*. Y_1 to Y_4 is male *C. carpio yuankiang*: P is parent: G_1 and G_2 is gynogenesis 1 and 2: F_1 to F_6 is filial generation 1 to 6.

Fig. 1: Flow Chart of Integration Breeding of Jian Carp

(3) Total productivity : The variety has been extended to 25 provinces and autonomous regions and cultured in more than 100,000 ha. The productivity is about 200,000 to 500,000 tons annually.
(4) Growth rate : it is 49.75%, 46.8%, and 28.9% higher than that of *Cyprinus carpio wuyuanensis, C. carpio yuankiang*, and Heyuan carp, respectively.

- Cold-tolerant strain of *Cyprinus carpio wuyuanensis*
  (1) Breeding institute : Heilongjiang Fisheries Research Institute.
  (2) Background : The parents are a native carp strain in Heilongjiang Province and *Cyprinus carpio wuyuanensis*. Through F_1 selfed , an individual with cold-tolerant factor, red color and all scale had been obtained in F_2. The individual was used as parent to keep the cold-tolerant factor combining with good characters from *Cyprinus carpio wuyuanensis*. In same culture conditions in frigid zone, its growth rate is 10% higher than that other varieties.
- Fong carp
  (1) Institute : Institute of Hydrobiology, Academia Sinica.
  (2) Background : Fong carp is a hybrid of female *Cyprinus carpio singguonensis* and male scattered mirror carp. Its appearance is similar to both female and male parent. In fingerling stage, the growth rate is obviously higher than parents. It has 50% to 62% higher growth rate as compared to female parent and 140% higher than male parent. Because of its hybrid vigor, it is welcomed by farmers.
  (3) Comparison between body length and body weight of Fong carp and its parents revealed the hybrid vigor both in fingerling and adult stages.
- Ying carp
  (1) Breeding institute : Chang jiang Fisheries Research Institute
  (2) Background : Ying carp is a hybrid of female scattered mirror carp and male F_2 of CyCa gynogenesis progeny, hence it possesses a tri-crossing vigor, its growth rate is 47% and 60.1% higher than its parents in one year old and two years old respectively.

Besides these varieties and hybrids mentioned above, there are Heyuan carp, Yue carp, Lotus carp, and scattered mirror carp to be cultured in different zone throughout the country.

One of the most serious constrains is improvement of the meat quality. By 1996, the total fish production has reached 28 million tons, of which freshwater fishery production was about 60%.

5. FUTURE RESEARCH AND PRIORITY

In addition to own abundant natural resources of carp, Chinese Government is paying more attention to the research projects dealing with genetics and breeding of fishes. On the basis of our experiment conditions and farming practices, as well as market situation, the future and priority of carp breeding is to focus on the following aspects.

5.1 Investigation of germplasm resources

Although a great deal of carp genetics and breeding research has been undertaken since 1970's, most germplasm resources of Genus Cyprinus and Family Cyprinidae have not been detailed. Hence, new techniques need to be used in identification of germplasm resources, such as isoenzyme analysis, DNA fingerprint technique, DNA probe and others.

5.2 Introduction of new species or varieties of carp

It is necessary or indispensable to introduce new germplasm from other regions or countries. For example, several varieties of common carp have been introduced into China since 1950's, these varieties are of benefit in providing wide germplasm to be selected.

5.3 Adoption of new techniques for breeding of carp

Besides traditional breeding methods and techniques, it is important to adopt new techniques to advance breeding progress. Since 1970's, gynogenesis, androgenesis, cell electric fusion, polyploid technique, and gene recombination have successfully been used in breeding program. On the basis of this, it is necessary to develop new techniques, especially, to improve the meat quality , like meat texture , meat flavor.

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CURRENT STATUS OF CARP GENETICS RESEARCH AND BREEDING PRACTICES IN INDIA

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INTRODUCTION

The carp germplasm resources of India, consisting of a number of major and minor carps are very rich. The major carp species, viz, the catla *(Catla catla)*, the rohu *(Labeo rohita)*, the mrigal *(Cirrhinus mrigala)*, the calbasu *(Labeo calbasu)* with their complimentary food habits are mutually compatible and grow relatively faster. These carps are thus readily a boon for the aquaculturists. Due to these qualities Indian major carps enjoy relatively wider distribution especially in the countries of Southeast Asia.

Because of their mutually compatible food habits, a multispecies culture technology (intensive/extensive) which is popularly known as composite carp culture has been developed during seventies. Chinese grass carp *(Ctenopharyngodon idella)* and silver carp *(Hypophthalmichthys molitrix)* have formed a welcome addition to Indian aquaculture scenario due to their relatively faster growth.

The intensive carp culture technology is mainly based on species ratio and stocking density manipulations and other management practices. These include intensive feeding, manuring, aeration and also replenishing water from time to time. The average fish production of 0.6 t/ha year from culture fisheries in the country could be increased to as high as 10-12/ha/y by adopting this technology. Recently, a production of 15-17 t/ha/yr has been also demonstrated through multiple cropping system.

However, in view of the need for sustaining aquaculture production and the environment through the system, any further increase in the production with already heavy inputs of feed and fertilizers, may not, perhaps be economically viable. Under these circumstances, the fishery workers had to look for other means of enhancing production from aquaculture to make it an economically sustainable profession.

Genetics is one such potential means to provide improved varieties that may thrive and perform the best. Development of varieties through optimum exploitation of the genetic potentials of the cultivated species to provide quality seed will be a positive step and very much needed during the coming decades if aquaculture has to be sustained.

Research for developing superior varieties of carps through genetic improvement methods are already in progress.

INSTITUTIONS INVOLVED IN ACTIVE CARP GENETICS AND BREEDING RESEARCH

The most actively involved institute in carp genetics and breeding research is the Central Institute of Freshwater Aquaculture (CIFA), Bhubaneswar, followed by the National Bureau of Fish Genetic Resources (NBFGR), Lucknow. Being a premier institute for freshwater aquaculture in the country, CIFA had initiated carp genetics research as early as late fifties as a sub-station at Cuttack of the Central Inland Fisheries Research Institute (CIFRI), Barrackpore, West Bengal, with simple hybridization among Indian major carps belonging to the three genera viz. *Catla, Labeo* and *Cirrhinus.*

RESEARCH COMPLETED

Hybridization

Several interspecific and intergeneric hybrids have been produced and evaluated for their utility in aquaculture. Most of these hybrids whether interspecific or intergeneric, were found to be fertile and F2 generation was also produced. In some cases the F2 hybrids were also found fertile. Some of them have exhibited faster growth rate than the slow growing parents and possessed more flesh content than the parent species. Several back-crosses and also triple cross hybrids have been produced among Indian carps.

Intergeneric crosses between common carp *(Cyprinus carpio* var. communis*)* and Indian major carps have yielded aneuploid sterile hybrids which may be very useful in aquaculture especially for reservoirs. As they are sterile, unwanted reproduction can be easily checked.

Cytogenetics

Cytogenetic studies include chromosome number and karyotype. About 250 Indian species of fishes have been studied, and chromosome number (2n) ranges from 16-100 with a peak of 48 and 50.

Comparative karyological studies of parent species and hybrids have also been made in relation to hybrid viability and fertility.

Chromosome banding studies such as C.G and NOR-banding have also been attempted. C-banding was tried in about 20 species including some carp species to define heterochromatin blocks. Carp species showed very low response to C-banding probably due to lack of well defined heterochromation blocks in their genome.

NOR-banding studies have been made in about 50 species including Indian major carps. Most species show only small NORs on a single pair of chromosome. Multiple NOR site has been reported in *Catla catla.*

Sister Chromatid Exchange (SCE) assay has been standardized in *Channa punctatus* to test the genotoxicity caused due to industrial effluents in aquaculture medium.

Genome manipulations (chromosomal engineering)

Investigations have been successfully carried out to find out and standardize the optimum levels of UV irradiation for genetical inactivation of major Asiatic carps and the thermal and pressure stock regimes to induce diploid meiotic and mitotic gynogenesis and to induce polyploidy (triploid/tetraploidy) in these carps.

Triploidy and tetraploidy have also been induced in tilapia, besides developing methods for the production of supermales of this species at Madurai Kamaraj University.

All male populations of tilapia could also be produced through hormone treatment.

Selective breeding

Carp selection work has been first initiated at CIFA with rohu *(Labeo rohita)* in collaboration with the Institute of Aquaculture Research (AKVAFORSK), Norway, in the year 1992. The project aims at improving the growth trait of rohu and develop a national breeding program for the distribution of genetically improved seed of this species to the fish farmers throughout the country.

The first phase of the project has been successfully completed by March 1996. During this phase various experimental procedures for field and laboratory including tagging procedures have been developed and standardized.

The stocks of rohu procured from different river systems viz. the Ganga, the Gomati, the Yamuna, the Sutlej and the Brahmaputra have been evaluated along with the farm (local) stock. It was observed that the differences between individuals of different stocks are narrower compared to individuals within the stock. The results showed a substantial additive genetic variation for growth in rohu.

An average selection response of about 13% has been observed in the first generation with a maximum of 24% in one of the replicates. The second phase of the project has also been initiated.

A second project on selective breeding of catla *(Catla catla)* has been taken up. This is a tripartite project among the University of Agriculture Science (UAS), Hasaraghatta, Bangalore, India; University of Wales, Swansea, UK; and University of Sterling, UK. This project mainly aims at investigating the present genetic status of domesticated catla in Karnataka State and design and indicate a suitable breeding program for genetic improvement of this important species.

The National Bureau of Fish Genetic Resources, Lucknow, has the mandate, for collection, classification and evaluation of information on fish genetic resources of the country along with cataloguing of genotypes. The Bureau has also taken up the task of maintenance and preservation of fish genetic material in coordination with other geneticists for conservation of endangered species.

Molecular genetics/gene transfer

During late eighties, experimental production of transgenic fish *(Labeo rohita, Cirrhinus mrigala)* has been carried out of *in vitro* recombinant DNA at the National Institute of Immunology, New Delhi.

Centre for Cellular and Molecular Biology (CCMB), at Hyderabad is at present concentrating on the production and evaluation of transgenics particularly carps and catfishes. It appears that the growth hormone gene of *Labeo rohita* and *Catla catla* has been successfully isolated.

Other institutions like Madurai Kamaraj University, Madurai, is also undertaking molecular genetics research.

The Department of Biochemistry, Bose Institute, Calcutta, is woking on developing methods for the identfication of species specific genetic markers for various applications in aquaculture including screening hybrids.

RESEARCH IN PROGRESS

Genome manipulations

Assessed the homozygosity level in mitotic gynogens of Indian major carps.

Evaluation of the performance of top-crossed progeny of gynogens for heterosis effect.

Inducing and production of allotriploids of carp hybrids (catla x rohu and calbasu x rohu) etc. Inducing tetraploidy in catla, calbasu, common carp and grass carp to produce triploids of these species on large scale for experimental studies.

Selective breeding

Selective breeding of Indian major carps (rohu and catla) is being continued to develop superior strains for aquaculture.

Molecular genetics

Cloning of isolated growth hormone genes and isolation of others, like disease resistant genes, standardization of RAPD techniques, etc.

BREEDING PRACTICES IN INDIA

Prior to the success of induced breeding of Indian major carps, the fish farmers used to depend mostly on riverine sources for the seed of these carps where they breed naturally. However, few farmers in the Midnapore and Bankura Districts of West Bengal used to follow traditional method of breeding the fish by simulating flooded riverine environment in a field having gradually sloping and undulating terrain for catchment of rainwater when the stocked brood fish of carps breed naturally. These are known as "dry bundhs". Later, this practice has been taken up by the state of Madhya Pradesh, followed by the State of Rajasthan. There are two types of Bundhs' viz. wet and dry bundhs. The wet bundhs are usually connected to some streams or river sources for almost permanent supply of water. Thus, during off season, these bundhs will be having some water. Unlike the wet bundhs, the dry bundhs remain dry except during monsoon months.

Of late, many modifications have taken place in bundhs and one such popular bundh is "Bangla bundh". It's an oval cement pond-like structure in two compartments, a small shallower and a large deeper one, divided by a slightly raised wall in the middle, with a perforated pipe line all around for water circulation. After the administration of hormone, the brood fish are released in the bundh and water is circulated for the precipitation of spawning.

The modern fish breeding technology is a gradual development by modification of the original hypophysation technique which was successful during late fifties at Cuttack, Orissa. The modern technology involves brood stock management, use of inducing agents and environmental monitoring. The crude pituitary extracts containing several other hormones, besides the gonadotropins, formed the basis for inducing spawning in carps which are now gradually replaced by many other products such as partially purified gonadotropins from carp and salmon (SG-G100), Human Chorionic Gonadotropin (HCG), Luteinizing Hormone-Releasing Hormone (LHRH) and its analogues, Salmon/Murrel Gonadotropic Releasing Hormones (SGn RH and m Gn RH) etc.

However, the breeding practices at present followed by the Indian Hatchery Managers and those fish farmers who are able to produce seed by themselves, in the pursuit of profit making are only aiming at meeting their targets in quantity by neglecting quality. As such, they do not show concern to any genetic norms with regard to aspects like maintenance of minimum effective population number and other management practices. The same brood stock with a narrow gene pool is very often used repeatedly for quite a long period and subsequent brood fish raised from the same sibs. Many seed produces were also in the practice of mass producing seed by breeding all the species together (mixed breeding). This is a very dangerous practice in terms of genetic degradation as it may lead to unwanted and undesirable hybridization.

The authorities with the help of scientific community should take immediate steps to bring some sort of awareness among the seed producers and convince them not to continue with such practices and avert the damage to the original gene pool, characteristic of the corresponding species.

FUTURE RESEARCH NEEDED

Hybridization

Hybridization between major and minor Indian carps and their evaluation for ploidy status and culture performance.

Genetic manipulation

Evaluation of allotriploids for disease resistance. Large scale production of triploids of common carp and grass carp after the successful induction and production of tetraploids of these species.

Investigation on the existence of different populations, if any, in various species of Indian major carps.

Integrated approach to enhance aquaculture production by clubbing ploidy/ genome manipulation and selective breeding methods.

Production and evaluation of transgenics of carps and catfishes and study the socio-economic impact of genetically manipulated superior stocks of fish.

A GENETIC IMPROVEMENT PROGRAMME ON *Catla catla* IN KARNATAKA STATE, INDIA - PRELIMINARY FINDINGS

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ABSTRACT

This paper presents preliminary results from a programme set up to chracterize and evaluate and subsequently improve cultured stocks of *Catla catla* in Karnataka State. Wild stocks were collected from four sites within the natural distribution of the species and population genetic analysis carried out on these and the existing hatchery stocks. These studies indicated that the existing isolated hatchery stocks have differentiated from each other but overall levels of genetic variation were similar between hatchery and wild caught fish. However, the conclusions from a survey of broodstock management practices points towards the likelihood of inbreeding and negative selection. Growth trails have compared the performances of existing catla stocks and crosses between them. These trials showed significant increase in yield from crosses between the two main hatchery stocks when compared to the parental stocks. These results suggested (i) significant inbreeding depression in these stocks; and (ii) that crosses between these hatchery stocks be used as an interim measure to improve production while a selective breeding program is developed to improve the performance.

INTRODUCTION

Karnataka has one of the richest water resources in India associated with two major watersheds, the Krishna and the Cauvery and a well developed irrigation system. The state has a relatively large diversity of the fish species representing the faunal diversity of the two major river systems. A few of these species form fisheries in rivers and some reservoirs and some species have a significant, but largely unexplored, potential for culture. However, the primary species used for aquaculture and enhanced fisheries are all non-endemic species, (principally the Indian Major Carps, catla *(Catla catla)*, rohu *(Labeo rohita)* and mrigal *(Cirrhinus mrigala)* native to Northern Indian rivers and the common carp *(Cyprinus carpio).*

The large majority of aquaculture is under state control with the Department of Fisheries (DOF) controlling fish seed supply through a network of state run hatcheries. There is a common perception amongst farmers and fisheries department officials alike that there is a steady decline in the performance of catla over recent years in terms of growth rate and yield. The concern appears greater for catla than for other species due more to its importance as the fastest growing species. Unfortunately, there are little if any, data available to either support or contradict this hypothesis of reduced performances. However, previous studies investigating the management of hatcheries from a genetic perspective have concluded that the management techniques applied are likely to result not only in inbreeding but also in negative selection for some commercially important traits (Eknath and Doyle 1985; Eknath and Doyle 1990). The breeding characteristics of the species itself renders it at risk of inbreeding under domestication. Broodstock replacement strategies may also further reduce effective population size resulting in inbreeding.

In addition to the problems associated with broodstock management, little was known of the founder stocks first introduced to the state at the beginning of the development of the industry in the early and mid 1960s. It was not clear where the fish came from or indeed how many fish were introduced and spawned to produce the first generation. It seems likely that there were few introductions and it is probable that founder effects also contributed to inbreeding.

The degree of inbreeding in domesticated stocks can be determined in a number of different ways, all of which will be evaluated in the project.

- From hatchery records enabling computation of effective population sizes and rates of inbreeding. This may also enable determination of any negative selection pressures.

- Direct measures of genetic variation in stocks through protein and DNA analyses.

- Indirect measures of genetic variation related to performances such as estimation of heritability and heterosis.

- Comparative performances testing of domesticated and wild stocks to determine the potential effects of inbreeding depression.

OBJECTIVES AND METHODOLOGIES

The overall objective of the catla component of the project was to determine extent of the problem of inbreeding in domesticated stocks of *Catla catla* in Karnataka state and to design and initiate a breeding program for the improvement of cultured catla stocks. Specific objectives and methods includes:

- To assess through survey and data collection in state hatcheries, the likely genetic status of the *Catla catla* stocks presently being used for aquaculture and in restocking programs in Karnataka.

- The genetic analysis, using allozyme, mitochondrial DNA (mtDNA), randomly amplified polymorphic DNA (RAPD), and tetranucleotide microsatellite techniques, of both the farmed stocks within the state and wild stocks collected from the North Indian rivers (Ganges, Brahmaputra and Mahanadi).

- Compare using appropriate analysis the levels of genetic variation and differentiation observed in the Karnataka stocks of Indian Major Carps and those of the wild stocks, to establish any changes in their genetic characteristics, to test the hypothesis that the domesticated stocks are inbred due to poor broodstock management practices.

- Develop and disseminate protocols for improving the genetic management of domesticated carp stocks in the state.

- Comparative performance testing on-station and on-farm. Initial trials concentrate on the comparison of key hatchery stocks and crosses between them. Later trials will compare the performance of hatchery stocks with wild caught fish.

- The strains with the best characteristics will be used to develop new lines using appropriate selective breeding techniques to further enhance their commercial importance.

RESULTS

Prior to conducting the experiments for the major objectives of the project we conducted a number of preliminary studies. For effective handling and experimentation of fish we first optimized the anesthetization of catla juveniles and adults using benzocaine (Basavaraju et al. MS[a]). Following evaluation of most of the presently available tagging methods we choose to use a combination of fin-clipping and elastomer dye marking as these gave the highest retention rates at an affordable cost (Basavaraju et al. MS[b]). Further to this, protocols were developed for performing crosses between hatchery stocks by transfer of chilled sperm and artificial fertilization.

LIKELY GENETIC STATUS OF *CATLA CATLA* IN KARNATAKA HATCHERIES

Hatchery survey

This problem was approached by visiting the larger Indian Major Carps producing hatcheries in the state to collect data on their broodstock management practices. Initial interviews revealed that there were actually only three hatcheries producing significant numbers of catla seed, Tunga Bhadra Dam (TBD), Bhadra Reservoir Project (BRP) and Kabini Reservoir Project (KRP). Few hatcheries maintained records of past hatchery management on which to base assumptions of the genetic status of stocks. Seed production at the hatcheries is based on the attainment of production targets. With this emphasis on quantity, little or no consideration is given to broodstock of fry quality, especially in relation to the genetic status of the stocks. The common practices of broodstock replacement seemed to be to retain a few fingerlings each year, normally these being collected towards the end of the spawning season, and usually representing no more than two or three families. These practices are likely to result in both inbreeding and negative selection. It was possible to develop estimates for average effective population sizes and rates of inbreeding in only a few hatcheries by applying the formula used by Eknath and Doyle 1990 (Table 1).

Table 1: Estimated effective population sizes and rates of inbreeding for major hatchery stocks of *Catla catla* in Karnataka state fish hatcheries

Hatchery	Species	No	Δ F (% per annum)
Tunga Bhadra Dam (TBD)	catla	55.5 (10.5)	0.9 (4.7)
	rohu	23.5 (12.3)	2.1 (4.0)
	mrigal	18.4 (13.5)	2.7 (3.7)
Bhadra Reservoir Project (BRP)	catla	18.4 (8.5)	3.5 (5.9)
	rohu	14.2 (6.9)	3.5 (7.2)
Kabini Reservoir Project (KRP)	catla	11.4 (4.7)	4.4 (10.6)

Figures in parentheses represent the comparative values obtained in the study of Eknath and Doyle (1990).

The estimates for effective population sizes vary from 55.5 to as low as 11.4 and for inbreeding rates from 0.90 to 4.40. At the high end of this range these are almost acceptable population sizes for short term domesticated although inbreeding would become a problem over many generations. The rates of inbreeding in the smaller hatcheries is unacceptably high and these data support the hypothesis that hatchery stocks are likely to be inbred, which may have brought about a reduction in their culture performances.

Genetic Analysis of Hatchery and Wild Caught Stocks

The preliminary data interpretation from the restriction endonuclease study of mtDNA and the RAPD analysis does not appear likely to reveal major differences between the strains either in terms of levels of genetic variation or in strain differentiation. Four tetranucleotide microsatellite probes were developed for use in Catla. These were analyzed for the broodstock in the key hatcheries and from the out-of-state wild and hatchery stocks. This analysis proved informative in determining overall levels of genetic variation (in terms of numbers of alleles and average heterozygosity) and in detecting differentiation between strains (Naish et al. , in preparation). These studies revealed that despite having a common source, the hatchery populations in Karnataka had differentiated from each other as a result of genetic drift or unconscious selection. However, there were significant differences in the number of alleles or in the average heterozygosity between the hatchery and wild caught stocks. While caution must be taken in the interpretation of these results due to potential differences in the inheritance of functional and non functional DNA sequences, these results seem to indicate that the hatchery stocks may not be as inbred as had initially been thought. One possible reason for this may be that the broodstock in the state hatcheries are used for several years, commonly up to 5 years of age and occasionally up to 6 or 7 years old. Thus the actual number of generations under domestication may be less than originally thought which may have resulted in an over estimation of inbreeding rates.

The analysis of the microsatellite data did not provide sufficient levels of discrimination to determine the origin of Karnataka hatchery stocks, but the degree of genetic similarity between these and the populations from the Ganges watershed would indicate that they originate from the Ganges.

GROWTH PERFORMANCE TRIALS

The first trial involved comparison of intra hatchery crosses for the three major hatcheries following collection of the same age seed from the hatcheries. These were nursed under near identical conditions prior to communal stocking at a mean weight of 9.3-9.8 g, following equalization of the sizes for the three strains. Fry were stocked communally in three 220-m^2 ponds at the Fisheries Research Station, Hesaraghatta and studied for growth for 24-weeks. There were no clear differences in growth performance of the strains and, on the basis of the results of this experiment, no one strain would necessarily be recommended over another (Table 2).

Table 2: Summary harvest data mean and s.e. (±) for communally stocked growth trial of three hatchery strains of catla

Strain	Mean harvest weight (g)		Mean harvest SL (cm)		Mean survival (%)	
	Untransformed	Transformed	Untransformed	Transformed	Untransformed	Transformed
BRP	$107.74^{a} \pm 2.72$	0.0068^{a}	$16.6^{a} \pm 0.14$	0.2586^{a}	$86.3^{a} \pm 5.22$	1.0589^{a}
TBD	$109.23^{a} \pm 3.26$	0.1478^{a}	$16.3^{a,b} \pm 0.15$	-0.0491^{a}	$70.1^{a} \pm 2.96$	0.7784^{b}
KRP	$102.62^{a} \pm 4.49$	-0.2881^{a}	$15.9^{b} \pm 0.22$	-0.4996^{b}	$39.0^{b} \pm 7.56$	0.4039^{c}

1 - Transformed for the mean weight of each pond using Z scores. Values in columns with different superscript letters are significantly different ($P<0.05$).

A second series of trials was completed in 1997 comparing inter-intra hatchery crosses between the stocks at TBD and BRP made during the monsoon of 1996. Same age juvenile catla from the two hatchery stocks and the reciprocal crosses between them were stocked under polyculture with rohu and mrigal at BRP and in two commercial farm ponds and under monoculture in a pond at Fisheries Research Station. The results shown in Fig-1, illustrate the apparent enhancement of culture performances in the crossbred fish compared to the pure intra-hatchery crosses.

In three polyculture environments the BRP stocks had very poor growth, whereas the TBD stock had poor survival and was characterized by mouth deformities and high rates of infestation of external parasites. These factors combined to produce very considerable and significant (P<0.001) increases in yield of the inter-hatchery crosses compared to intra hatchery crosses, ranging from 120-245%. While these result indicate that there exists a positive heterosis for growth in the inter-hatchery crosses further growth trials are required to confirm this observation.

Summary, implications and future plans

A survey of hatchery practices indicated the likelihood of inbreeding and negative selection and domesticated stock of catla in the key producing hatcheries in the state. Genetic analysis using four tetranucleotide microsatellite loci showed differentiation of the hatchery stocks from each other, and pointed towards a gangetic origin for the hatchery stocks. However, the microsatellite loci had similar number of alleles and levels of heterozygosity in the hatchery and wild caught stocks indicating that genetic variation at these loci has not been lost during the process of domestication. Results from growth trials indicated that there were no significant differences in the growth performances of the key hatchery stocks but the inter-hatchery stocks produced highly significant increases in yield. While this results are somewhat contradictory, it seems probable that some inbreeding depression of negative selection is being expressed in the hatchery stocks and gains could be from culturing the strain crosses.

It has been recommended to the Department of Fisheries of Karnataka that some present or future broodstock be exchanged between the two hatcheries to enable large scale production of crossbred fish. There is an interim measure to provide the potential to improve performance of seed produced in these hatcheries.

Subsequent growth trials will attempt to confirm the superiority of the inter-hatchery crosses and will compare the growth performances of hatchery and wild caught stocks. Informed decisions will be taken together, with the Department of Fisheries. In the subsequent choice of strains in the optimization of broodstock management practices, and in design of long term and sustainable program for the genetic improvement of catla in Karnataka. It is hoped that approaches developed for genetic management and improvement of catla will be applicable to other carp species and in other regions where similar problems exists.

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CURRENT STATUS OF CARP GENETICS RESEARCH AND BREEDING PRACTICES IN INDONESIA

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INTRODUCTION

Selection is the oldest carp genetics research in Indonesia. It started in 1919 and ended in 1930 with the "Punten" strain as an end product of the program. The study itself concentrated in fixing greenish coloration of the carp population and body depth of carp preferred in the country. Subsequent to that, no genetic research was undertaken till 1963, when the government research institute continued the selection program for producing a new line with specific phenotypic characters e.g. light body coloration (mostly yellow), membranes covered eye, elongated body shape, which resulted in "Sinyonya" strain.

During 1963 to 1970, there were no reports on carp genetics research. However, Ardiwinata (1971) collected some characteristics data on the well known population of carp in country. It reported that there are nine stocks of common carp based on the morphological body shape and behaviour. Those stocks mostly emerged from the breeding practices under farm conditions through the farmers creativity to collect some new variants from the population. Breeding activity of the new variants for several generations was posible to fix variability.

The genetics research again started in 1974 with the intensive carp culture in small continuous flow (running water) systems. The study was necessitated by the demand for better quality fish for the industry. Special attention in genetics research and breeding was focused on mainly improving the growth performance. However, there was no coordination among the institutes involved in the fish genetics research.

INSTITUTES INVOLVED IN CARP GENETICS AND BREEDING RESEARCH

During 1919 to 1980, only Research Institute for Freshwater Fisheries (RIFF) undertook the carp genetics and breeding research. From 1980 to 1990, besides RIFF, Bogor Agricultural University (BAU) undertook genetics research. During 1980 to 1990, other universities (Gajahmada/GU, Brawijaya/BU and Pajajaran University/PU) and Agency for Assessment of Applied Technology (AAAT) joined the genetics research.

In 1993, the Indonesian Network on Fish Genetics Research and Development (INFIGRAD) was established as the Indonesian chapter of INGA. Under the network, exchange of information is being done through regular annual meetings to evaluate the research progress and to find solutions to problems. Following the same year, Directorate General of Fisheries (DGF) appointed a new director in-charge of national breeding program.

CURRENT STATUS OF CARP GENETICS RESEARCH COMPLETED AND RESULTS

Characterization

The first identification of some morphological characters was undertaken for the well known common carp stocks e.g., Majalaya, Punten, Sinyonya dan Taiwan in 1976 (Hardjamulia and Suseno, 1976). The truss morphometric technique of multivariate morphometric analysis approach was also used to distinguish morphological shape variation between common carp populations and among color morphs within populations (Matricia, 1990). Multivariate statistical analysis of size and shape revealed that the two common carp stocks collected from Cianjur (West Java) and Payakumbuh (West Sumatra) can be classified into two distinct morphological groups.

Other identification studies revealed that closely related color morphs have closer distance coefficients on the dendrogram of phenetic similarity (Sumantadinata and Taniguchi, 1990). Using 10 characters, they showed that green strains represented by Majalaya and Punten, are closely related. However, the yellow colored Sinyonya has the greatest distance coefficient to Majalaya and Punten. When allele frequencies and genetic variability of six stocks of common carp collected from Indonesia were evaluated, twenty-three loci were identified from 11 enzyme and protein systems. Five loci were polymorphic for the Indonesian stocks. Whithin the stocks, the phenetic relationship among the Local, Domas and Majalaya stocks was very close; however, the Punten, Taiwan and Sinyonya was more divergent.

Color inheritance test by single-pair intra or inter-color matings of the green, yellow and red morphs to give F1 generation gave evidence that these phenotypes have the genotypes proposed by previous workers. In this study, we proposed other gene symbols for the scale type ie., T (non-transparent) for wild type and t for transparent (Gustiano and Phang, 1994). Two loci (R_1 and r_1, R_2 and r_2) with the additive gene effect, were probably involved in the production of yellow/red pigment, which are present in the yellow and red morphs. The dominant alleles controlled the amount of pigment produced (Gustiano, 1995).

Random Amplified Polymorphic DNA (RAPD) test on Majalaya, Punten, Sinyonya, Merah, Kaca dan Domas strain of common carp (Aliah *et al.*, 1996) showed that the primer operon of OPA-03, OPA-09, OPA-10, OPA-13, OPA-15 and OPA-20 used in this study did not produce any polymorphic of fragment DNA. However primer OPA-14, OPA-16, OPA-17, OPA-18 and OPA-19 revealed 19 polymorphic profiles on gel electrophoresis.

Evaluation

Variation of color morph frequency and growth variation among color morphs were successfully detected under farm and experimental pond conditions. Matricia (1990) reported that growth rate differences among color morphs of common carp were a function of the environment (farm) where the populations were reared. Growth comparison among 3 color (blue, green and red) morphs under communal rearing in 3 grow-out floating net cage farms (Gustiano, 1993) and separate testing in experimental floating net cages in Cirata Reservoir (Gustiano *et al.*, 1995) showed that in general the dark color morph of common carp (blue and green) has better growth compared to the light color morph (red). Both rearing practices showed an indication that there was no environmental factor in terms of competition for feed which influenced the growth. Therefore, the difference was solely caused by positive pleiotropic effect from dark color morph carrying gene dominated to light color.

Evaluation of 21 collections of common carp from the islands of Java, Sumatra and Bali, was undertaken and the collections were ranked based on hatching rate, survival, growth and disease resistance during the first growth stage (3 - 5 cm in size) (Nugroho in Sudarto, 1993). The result suggested that four strains namely Rajadanu-Kuningan, Wildan-Cianjur, Sutisna-Kuningan and Cangkringan-Yogyakarta performed better (Hardjamulia et al., 1996). The best among those 4 selected strains is Rajadanu-Kuningan with regard to growth in 3 months at Cijeruk research installation. Sutisna-Kuningan grew faster among them and attained better growth in 9 months rearing at Wanayasa breeding center (Sudarto et al., 1994).

Selection intensity of common carp in rice-fish ponds indicated significant difference between the two color types, the dark color type (green and blue) with better survival than the light type (red and yellow). Due to this finding the farmers were instructed to use dark colored common carp to increase their harvest in rice-fish ponds where many predators exist (Sudarto, 1993).

In the case of disease resistance test, Majalaya was more resistant to Myxobolus at the age of 45 days (Hardjamulia and Suseno, 1976). According Komarudin (1986), Punten, Taiwan, Sinyonya, local and Majalaya had similar susceptibility to Myxosporidia. Supriyadi et al. (1996) explained that ranking done for 21 collections indicated, Rajadanu has better disease resistance to *Aeromonas hydrophila* and some ecto parasites, than the others.

Hybridization

In interspesific hybridization, Majalaya x Taiwan gave better growth performance as compared to the others in 45, 60 and 90 days rearing periods (Hardjamulia and Suseno, 1976). Hybrids of Taiwan x Punten showed a heterosis vigour (Suseno et al, 1983) at the end of 6 months rearing period. However, no significant differences were observed in hybridization among other carp stocks (Jangkaru *et al.*, 1987). Komarudin and Effendi (1990) reported that there were no significant differences in the degree of parasite infection among Majalaya, Sinyonya and their hybrids. Intergeneric hybridization studies indicated that the cross between carp x Java carp was better than carp x nilem carp (Gustiano *et al.*, 1988; Sumantadinata, 1992).

Gynogenesis

Time for retaining the second polar body and the first mitotic division were; 2-4 min. and 40-45 min. or 55 min.. (two peaks) respectively. The best duration for 40°C heat shock was 1.5-2 min., and for 42.5°C, 1 min. The UV-irradiated sperm of nilem, tawes were useful for inseminating eggs in gynogenesis of common carp (Ahmad and Gustiano, 1990; Sumantadinata et al., 1990). The gynogenetic offspring were evaluated for inbreeding depression, quantitative and qualitative character variability (Sumantadinata et al., 1994), performance test and sex reversal.

RESEARCH IN PROGRESS

Research done in various institutions has been reported in a paper submitted for INFIGRAD network meeting, covering characterization, evaluation (strains comparison and hybridization), selection and genome manipulation. List of study areas and implementing institutions are: characterization (by RIFF, AAAT), evaluation (RIFF, BAU, AAAT, BU and DGF/Freshwater Aquaculture Development Center(FADC)), selection (RIFF, BAU, FADC), hybridization (RIFF, IPB and FADC), and genome manipulation (RIFF, BAU, AAAT, FADC, GU and PU).

CARP CULTURE AND BREEDING: IMPROVEMENTS AND CONSTRAINTS RELATED TO GENETICS

Traditionally common carp are cultured in rice fields, stagnant and running water ponds, and cages in a stream. They depend mainly on natural food as source of nutrition. In cage culture, they feed mainly on the organic materials carried down stream. Supplementary feeding with kitchen waste, agricultural products or fresh leaves are given occasionally. There are two types of conditions for spawning: 1) spawning -area inside a fry pond and 2) fry pond. In the first, spawning-area is prepared inside a fry-pond. The area is surrounded by a fence (usually bamboo-matting), somewhat higher than the water level. One gate is installed in the fence, through which the breeders are chase out after spawning. The second one uses "kakaban", or palm fiber mats, as eggs collectors. The kakaban, covered with eggs, are transferred to the fry pond.

In recent years, common carp culture has become an industry in the newly developed culture systems e.g., running water pond during 1974 to 1985 and floating net cages from the beginning of 1980. These developments are resulting in looking for better quality fish in terms of growth performance and disease resistance. In view of this, the government is giving importance for fish quality improvement studies. In the past, the national breeding program was not developed. So the genetics research was sporadic and hence became difficult to review the realized improvement. However, through separate studies in the institutes and universities, some basic genetic information essential to judge the national breeding program in the future was collected. Besides that, the potential genetic carp stocks have been tested and distributed to some breeding centers. Collaborative work between breeding centers and well established farms showed similar results when they used the same stocks.

One of the main problem of common carp culture in Indonesia is early sexual maturation, particularly in males. Inbreeding might be a problem that can effect growth rate since fish farmers in general have small number of broodstock, sometimes less than 10 fish. Fish disease, notably *Aeromonas hydrophila* and *Myxobolus* have been a common problem, especially at fry stage.

FUTURE RESEARCH NEEDED

In the past, national breeding program for common carp in Indonesia was not in the context of genetic improvement, but to intensify fry production to ensure the availability of fry and fingerlings for grow out operations.

There is strong need for a breeding program to improve the culture performance of common carp stocks. So the strategic plan of AARD (Agency for Agricultural Research and Development) for 1995-2005 gives high priority to the genetic improvement of fish. The most important economic traits in common carp are growth rate, delayed sexual maturation, disease resistance and body composition/texture. In accordance with this, the Indonesian Network of Fish Genetics Research and development (INFIGRAD) in co-operation with the International Network on Genetics in Aquaculture (INGA) has taken the initiative to establish a breeding program for common carp in Indonesia (Gjedrem et al, 1997).

In this program INFIGRAD will have its role as research co-ordinator, and the members may contribute in the research and development under responsibility of RIFF, Sukamandi, which will serve as the breeding center where mating, testing and selection will take place.

As RIFF develops and gets experience in running the breeding program, mating, testing and selection will become more and more routine work. This activity will also occupy much of research capacity at RIFF. At that stage, INFIGRAD may assist in reorganizing the breeding program in order to reduce the routine breeding work at RIFF and develop other breeding centers.

The effect of breeding program depends very much on dissemination of the obtained genetic improvement rapidly to the farmers. AIAT (Assessment Institute for Agricultural Technology) and FADC (Freshwater Aquaculture Development Center) can play a central role in the dissemination of the improved fish. It is important that INFIGRAD coordinates this process.

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CURRENT STATUS OF CARP GENETICS RESEARCH AND BREEDING PRACTICES IN THAILAND

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INTRODUCTION

The total freshwater aquaculture production in Thailand in 1994 was estimated 173,947 tons, of which 32,587 tons were carps. The carp species cultured are silver barb *(Puntius gonionotus)*, common carp *(Cyprinus carpio)*, rohu *(Labeo rohita)*, mrigal *(Cirrhinus mrigala)* and Chinese carps. Most of the research has been carried out on biology, reproduction and breeding techniques. Due to the poor performance of hatchery produced seed, genetic research has been focused on these species.

INSTITUTES INVOLVED IN CARP GENETICS AND BREEDING RESEARCH

The institutes involved in carp genetics and breeding research are:

1. National Aquaculture Genetics Research Institute (NIFI), Department of Fisheries
2. Inland Fisheries Division, Department of Fisheries
3. Faculty of Fisheries, Kasetsart University

CURRENT STATUS OF CARP GENETICS RESEARCH

Research completed and results

This section reviews some completed carp genetics researches in Thailand.

1. **Silver barb *(Puntius gonionotus)***

Silver barb is the most important carp species cultured and stocked in reservoirs in Thailand. It is found naturally throughout the country in rivers, reservoirs and swamps. The production in 1994 was 27,200 tons, valued at 594.31 million Baht (Ca. US$23.77 million) in value, and ranks first by both weight and value among carp species cultured in Thailand (Thai Department of Fisheries, 1996). It is mostly cultured in ponds and paddy fields. Seed fish is produced in both public and private hatcheries.

Females in this species grow significantly faster than males and are also preferred by consumers because of the ovaries, which are a delicacy. This sexual dimorphism combined with the biology, culture systems and consumer demand suggested this species as being a suitable target for monosex female culture. While direct feminization with steroid hormones at the fry stage may have been difficult to replicate and integrate on a commercial scale and may have led to adverse consumer reaction, models for "indirect" monosex female culture (involving manipulation of the sex determination system rather than direct feminization with steroids) of this species have been tested since 1990.

Nothing was known about the sex determining mechanism in silver barb. Some basic research on the sex determination mechanism was carried out using gynogenesis, where the paternal (sperm) genetic material is inactivated before fertilization and then the female chromosomes are doubled after fertilization to give fish with the normal two sets of chromosomes, of only female origin. The sex determining genes are likewise affected and the resultant sex ratios give information about the sex determining system. The gynogenesis procedure was first developed, then gynogenetic fish and controls from ten different experiments were grown to an age when they could be sexed: the gynogenetics were all female, while the controls were not significantly different from 1:1 male : female ratio. This suggested that this species has female homogamety (XX) for sex determination (Pongthana et al., 1995).

Neomales or XX-males (genetically female but actually functional males) were produced by hormonally masculinizing gynogenetic fry using 17α-methyltestosterone (MT) at 25 mg/kg in the diet, for a duration of 4 or 5 weeks starting two weeks after hatching. The crosses between these neomales and ordinary females gave all-female progeny, which supports the hypothesis of female homogamety and establishes that large-scale production of monosex females is feasible in this species. A growth trial comparing monosex female groups with mixed-sex groups in pond culture showed a significant increase in yield from the monosex groups (Pongthana et al., 1997) (in press)). The commercial production of monosex female silver barb is in progress.

Comparative growth performances of diploid and triploid silver barb was reported by Koedprang and Na-Nakom (1994). Triploid silver barb was induced by subjecting fertilized eggs to a cold shock of 2°C for 10 min commencing 0.5 min after ferlitization which resulted in 64-100% triploidy. Sex ratio in triploids skewed males, while 1:1 ratio was observed in the control. Oogenesis in triploid female was retarded, while small number of spermatozoa were observed in triploid male. Nuclear volume in triploid fish was significantly higher than that in diploids. No significant difference in growth between diploid and triploid fish at 10 months of age was observed.

Genetic diversity and socioeconomic aspects of silver barb culture in Khon Kaen province were investigated in order to study the feasibility of development and differentiation of new, locally adapted breeds in situations where there is focus on market-driven decision making by small-holder commercial and subsistence farmers and fry suppliers trying to improve their own broodstock (Uraiwan et al, 1996). Five hatcheries, 19 grow-out farms, 6 traders and 6 consumers were investigated. Results from the socioeconomic studies indicated that there are three different models of fingerling/fish distribution from hatcheries to consumers; (1) mobile trading system (hatchery→mobile traders→grow-out farms→consumers), (2) membership system (hatchery→contract persons/village head men→grow-out farms→fish traders→ consumers), and (3) farm gate system (hatchery→grow-out farms→consumers). The nuclear DNA analysis of fish blood sampled from 5 hatcheries indicated that the heterozygosity of these populations ranged from 0.748 to 0.819.

Spatial genetic structure of silver barb populations in Thailand was reported by Kamonrat (1996). Microsatellite DNA markers were developed from a Thai silver barb genomic library and used to study various aspects of the genetics of their populations in Thailand in order to provide means for evaluating management policies for the species in terms of conservation and genetic improvement. Twelve natural populations from three rivers and 29 hatchery stocks from the central and northeast regions of Thailand were studied. Genetic variability was high in both groups of populations. Multidimensional scaling analysis of genetic distances revealed the discreteness apparent between watersheds among natural populations both in native and hatchery stocks indicating rich genetic resources of this species in Thailand. However, there was evidence that stock management may pose a threat of losing or altering genetic integrity of both natural and hatchery populations. Mixed stock analysis of the fish sampled from the rivers indicated that 75% to 96% were from hatchery populations. This high genetic contamination of natural populations was undoubtedly the consequence of restocking programs in which millions of fingerlings of this species are released in rivers each year. Evidence of reduction of genetic integrity between regions was also observed in stations due to stock transfer. The results suggested an urgent need for genetically based stock management policies for both natural and hatchery populations.

The potential use of microsatellites for broodstock improvement in aquaculture was also studied. Pedigrees of individuals were successfully established in a large communal rearing by using one to five microsatellites. The ability to identify individuals allowed a complicated genetic experiment and selective breeding work to be conducted in places where facilities were limited. Results are considered to be more reliable because environmental variances are accounted for as fish are grown together from birth. In this study, heritability of growth traits in three stocks of silver barb were estimated where all families were reared together. The estimates ranged from 0.193 to 0.523 suggesting that selective breeding in this species should result in good progress. However, heterozygosity in the largest individuals was greatly reduced, indicating that rapid inbreeding is very likely in simple means selection strategies.

2. Common carp *(Cyprinus carpio)*

The common carp is also one of the species cultured and stocked in reservoirs and has been introduced to Thailand more than 80 years back. It is found naturally throughout the country in rivers, reservoirs and swamps. The production in 1994 was estimated at 2,818 tons with a value of 73.33 million Baht (Ca. US$ 2.93 million), ranking second in both weight and value among the carp species cultured in Thailand (Thai Department of Fisheries, 1996). It is cultured in ponds, paddy fields and ditches. Seed fish is produced from both public and private hatcheries.

Growth performance of Maenam Mun and local races of common carp was investigated in Ubonrachathani Inland Fisheries Development Center (Sihapitukgiat et al., 1992). Fish was communally stocked in six 50-m^2 ponds at the same stocking rate of 2 fish/m^2. Data on growth was collected every 20 days. There was significant difference in growth rate between these two races. The Maenam Mun race was 13% larger than the local race at final harvest.

Comparative growth performance was investigated among three lines of common carp including F21, F22 and TH (local strain). The F21 line was a progeny produced from the cross between female local strain (TH) and male TH-P31 hybrid (male progeny from the crossing of male P31 Hungarian and female local strain). The F22 line was a progeny produced from the cross between female TH-P31 hybrid (female progeny from the crossing of female P31 and male local strain) and male local strain. The average growth rates of F21, F22 and TH strain at an age of 5 months were 3.008, 2.643 and 2.333 g/week, respectively. The F21 had the highest growth rate, 13.81 and 28.93% significantly faster than the F22 and local strain, respectively (Jala 1993).

Introductory cross was tested to improve the body configuration of the local strain (Pitsanulok stock) of common carp aiming to increase the body depth and decrease the head length and depth (Kamonrat et al., 1996). The selection experiment was initiated in 1985. A series of back-crossings with the local strain of the hybrid between the Hungarian (P-31) and the local strains was carried. Two local paternal and maternal back-cross lines (P31LOC and LOCP31) were created. After 3 generations of selection, these two lines showed significant difference in overall body configuration. Both lines had significantly smaller head, but higher body depth and caudal peduncle than the local strain. The body configuration of this fish appeared to be maternally predominated inheritance. The LOCP31 had similar "big belly" as the local strain, while the P31LOC didn't show this figure. These findings suggested the possibility to improve the body configuration of the local strain through out-crossing with the Hungarian strain (P-31).

Growth performance of the Hungarian strain of common carp F_1 hybrid (P-31R) between scaled and mirror carp was investigated under 2 different environmental conditions against the local strain (Pitsanulok stock) (Jala et al., 1996). In the first experiment, both strains were communally stocked in a 70m^2 concrete pond. The Hungarian hybrid grew significantly faster than the local strain at ages of 6, 8, 10, 11, 12, 13, 14, 16 and 18 months. The average length and weight of the Hungarian hybrid and the local strain at 18 months old were 33.17 and 27.03 cm, and 731.83 and 432.1 g, respectively. In the second experiment, both strains were separately stocked in two earthen ponds each. No significant difference in growth between the strains was observed at ages 3, 5, 8, 10, 11, 12, 14 and 16 months. These findings suggested the existence of genotype-environment interaction in these fish. The Hungarian carp has been selected for growth trait under a "sheltered life" environment and less adapted for harsh environments, while the local strain, although has no history of planned selective breeding, has long been exposed and adapted to harsh environments. In addition, the tested Hungarian hybrid was the second generation born in Thailand. The fish may be more sensitive to local conditions than the local strain.

3. Indian carp *(Labeo rohita)*

The Indian carp also known as 'Rohu' was introduced from India to Thailand in 1968. It is found naturally throughout the country in large reserviors and swamps. The production in 1994 was estimated at 1,783 tons in quantity, with a value of 32.64 million Baht (Ca. US$1.30 million), ranking third in both weight and value among the carp species cultured in Thailand (Thai Department of Fisheries, 1996). This is cultured in ponds, paddy fields and ditches. Seed fish is produced from both public and private hatcheries.

Studies were undertaken by Supsuksamran (1987) to investigate the growth rate of this species raised in cages and to estimate the heritability as well as the genetic, phenotypic and environmental correlation for body weight, total length, body depth, head length and girth of fish at ages of 118, 202 and 285 days. The half-sib analysis was tested from the parents of 5 dams and 15 sires with each dam mated to 3 sires. Nested, randomized block design which contained 40 fish/cage, 2 cages/sire was used. The average daily gain and the specific growth rate at ages of 168-195 days were 0.33 mg/day and 0.7%/day, respectively. Crosses involved with the biggest dams had the highest average daily gain and specific growth rate. Estimates of heritability for body weight, total length, body depth, head length and girth at ages of 118, 202 and 285 days were small and ranged from 0.002 to 0.138. Genetic correlation between body weight and total length at ages of 118,202 and 285 days was large, ranged from 0.969 to 2.387. Genetic correlation between total length and body depth, total length and head length, total length and girth at 285 days old was also large and ranged from 0.483 to 1.022. Phenotypic correlation between body weight and total length, total length and body depth, total length and head length, total length and girth at ages of 118, 202 and 285 days was large and ranged from 0.903 to 0.970. The environmental correlation between traits studied at ages of 118, 202 and 285 days was large and ranged from 0.901 to 0.976.

4. Chinese carps

Three species of Chinese carps are cultured in Thailand: silver barb *(Hypophthalmichthys molitrix)*, bighead carp *(Aristichthys nobilis)*, grass carp *(Ctenopharyngodon idellus)*.

Chinese carps were introduced from China to Thailand more than 100 years back. These species have been stocked in a number of public waters where they have become part of extensive culture fisheries. The production was smallest among carp species cultured in Thailand, estimated at 288 tons in 1994. They are mostly cultured in ponds, stocked incombination with one another in the ration of 2:1:1 for grass, silver and big head carps. Seed fish is produced from both public and private hatcheries.

The genetic parameters of big head carp was studied by Nukwan (1987). With the nested design, each female of three different sizes was bred with three males. Fingerlings from each mating were reared separately in hapas for 3 months, and then transferred to separate cages for 9 months. Mean heritability estimates of their offsprings at ages of 124, 208, 292 and 362 days were 0.172, 0.095, 0.152 and 0.035 for body weight, and 0.179, 0.080, 0.095 and 0.036 for total length, respectively. Genetic, environmental and phenotypic correlation estimates for body weight and total length ranged from -0.0007 to 1.239, 0.927 to 0.957 and 0.925 to 0.960, respectively.

RESEARCH IN PROGRESS

1. Development of monosex culture in *Puntius* species.
2. Using circuli spacing technique to compare growth rate and broodstock management of different strains of *P. gonionotus.*
3. Structure and genetic variation of silver barb *(P. gonionotus)* stocks from four Inland Fisheries Development Centers of Thailand.
4. Cryopreservation of the XX-male silver barb spermatozoa.
5. Comparison of the body shape and growth rate between improved and local strains of common carp.
6. Genetic improvement of the Hungarian and local strains of common carp.
7. Allozyme genetic data in three common carp strains.

CARP CULTURE AND BREEDING: IMPROVEMENTS AND CONSTRAINTS RELATED TO GENETICS

All cultured carp species in Thailand can be spawned through hormonal injections. The hormones normally used for induced ovulation in these species are: 1) the pituitary homogenate (PG) from the Chinese carps, 2) commercially available human chorionic gonadotropin (HCG), 3) luteinizing releasing hormone (LHRH) mixed with Dopamine antagonist, and 4) 'Suprefac' mixed with 'Domperidone'. Artificial or natural spawning is practiced after induced spawning. Most public and private hatcheries use wild captured fish as broodstock with regular replacements. In small hatcheries, cultured fish left in the ponds after final harvest is usually used as broodstock. Poor quality seed fish comes mostly from these hatcheries. No broodstock management has been practiced. Very few hatcheries have used genetically improved breeds as brood fish. According to the restocking programs of the Thai Department of Fisheries, more than 50 million hatchery produced seed are released to rivers, reservoirs and swamps throughout the country each year. In addition, seed or stock transfer has occurred throughout the country due to most hatcheries being located in the central region. These activities have caused the genetic contamination of the hatchery and natural populations.

FUTURE RESEARCH NEEDED

1. Setting up the National Breeding Program for hatchery produced carp species.

2. Developing genetically improved breeds of carp species.
3. Applying monosex female culture technology to genetically improved silver barb stocks.
4. Studying the genetic structure of carp populations in Thailand.
5. Conducting research on cryopreservation of carp species.

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CURRENT STATUS OF CARP GENETICS RESEARCH AND BREEDING PRACTICES IN VIETNAM

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1. INTRODUCTION

Aquaculture production in Vietnam has increased from 360,750 t in 1990 to 411,000 t in 1996.

Table 1: Aquaculture production in Vietnam during 1990-1996

Year	Total fish production (tons)	Fish production from aquaculture	
		Tons	%
1990	978.880	360,750	31.3
1991	1,066.330	355,910	31.5
1992	1,086.800	349,630	32.2
1993	1,166.169	372,845	32.0
1994	1,211.496	333,022	27.5
1995	1,344.140	415,280	30.9
1996	1,373.500	411,000	29.9

Unfortunately, due to lack of proper collection of fisheries statistics in the country, separate statistics for freshwater and brackishwater aquaculture production, as well as data on annual production of major groups of finfish, crustaceans, molluscs and aquatic plants are not available. Mariculture in Vietnam has just initiated and its production is not considerable. Shrimp culture is a major activity in coastal areas and shrimp contributed about 10-20% of total aquaculture production (Table 2). It means, that production from freshwater accounted for 70-80% of total aquaculture production.

Table 2: Shrimp production (mainly *P. monodon*) in Vietnam

Year	1990	1991	1992	1993	1994	1995	1996
Production	37,000	40,000	47,000	60,000	70,000	75,000	70,300

Among freshwater cultured fish species, carps play the most important role in freshwater aquaculture, particularly in northern region of the country. However, the number of genetically improved carp breeds in use in aquaculture systems is very limited. Therefore, in recent years, domestication and genetic enhancement of farmed fish through genetic and selective breeding programs has become an important activity for several research institutions including Research Institute for Aquaculture No. 1, Research Institute for Aquaculture No. 2, Hanoi National University and National Institute of Biotechnologies.

2. CURRENT STATUS OF CARP GENETICS RESEARCH

2.1 Genetic characterization

Apart from studies on intraspecific classification and identification of Vietnamese common carp and the research on restoration of purity of Vietnamese and Chinese silver carp stocks (Thien, Dan - Report in this workshop), genetic characterization has been done for different strains of common carp namely Vietnamese white carp, Hungarian scale carp and Indonesian yellow carp with a view to undertake selective breeding. Significant differences were observed among these common carp strains in morphology and growth performance. Analysis of the total protein in blood serum, albumin and globulin of the carps by electrophoresis showed that there were differences in quantity of the total protein and its fractions among these strains. There were no significant differences in distribution of phenotypes as well as in frequency alleles. Haemoglobin of all the studied strains of common carp was monomorphism (Thien 1988). In our common carp breeding program (Thien 1996) for assessing the level of genetic variability of selected fish in 5^{th} generation. some isozymes, namely LDH, MDH, AAT and EST from blood, heart, liver and muscle of the carps in three stocks were studied by electrophoresis in 6% polyacrilamide gel. All the above mentioned isozymes were polymorphic and the electrophoregrams included 2-6 bands. The data on comparison between the stocks showed that LDH in muscle and liver, MDH in liver and muscle as well as AAT in blood, heart and muscle were identical for all the stocks. The electrophoretic patterns of AAT in liver, EST in heart and muscle were also similar, but there were some differences between the stocks in frequency of the bands. Identification of the stocks could be done only by using parallel analysis of LDH, MDH, and EST in blood. For each stock, the identity of above mentioned isozymes was very high. Thus, genetic variability of the carps within the stocks after 5 selected generations has probably declined seriously.

2.2 Genetic management

The studies on gynogenesis have been undertaken for common carp and African catfish *(Clarias gariepinus)* with the use of ultraviolet radiation and cold shock. In the experiments on common carp and catfish, the highest number of diploid gynogenetic fry was 7.7% and 8.4% respectively. All these fry were females confirming their homogametic sex. Unfortunately, mass production of gynogenetic fish for use in the hybridization or selective breeding programs was not done. (Nga 1986).

An applied research program on mass production of all-female silver barb using gynogenesis and sex reversal through hormone treatment to produce neo-males is being carried out at RIA 1.

Other applied research on YY male technology for production of all male Nile tilapia (GMT) has also been initiated at RIA 1. The experiments to produce sex-reversed female (XY) through treatment of different doses of diethylstilbestrol (DES) have been done in 1996. Identification of sex-reversed females (XY) by progeny testing has been conducted.

In the last three years, research on gene transfer for gold fish has been carried out by using mainly micro-injection method at the National Institute of Biotechnology (Cuong et al. 1995). To facilitate injection, some experiments in elimination of egg's chorion have also been conducted.

2.3 Genetic improvement

Commercial hybridization

Preliminary studies on interspecific crosses of carps, as well as tilapias have shown that these interspecific hybrids do not have good prospects for culture. Hybrid between female bighead carp and male silver carp possessed high viability in fry and fingerling stages compared with their pure sibs. However, the growth rate of these hybrids in all the experiments were less than that of silver carp which has always lower growth rate than that of bighead carp. It was concluded that this hybrid is not profitable for culture (Thien and Tuong 1983).

The experiments for comparing the growth of two tilapia species indicated that *Oreochromis niloticus* grew nearly twice as fast as *O. mossambicus*. The hybrid obtained by crossing between these species grew moderately in comparison with their pure sibs. In the case of crossing female *O niloticus* with male *O. mossambicus*, the sex ratio the hybrid population changed and 70-80% of hybrids were males, but in reciprocal cross only 27-32% were males. It is clear that these hybrids are not profitable for culture either (Thien Tuong 1983).

Although in Vietnam eight varieties of local common carp were investigated, attempts to determine the effectiveness of heterosis by crossing these varieties were not successful. The hybrids obtained by crossing Vietnamese white carp and Hungarian carp possessed the best characteristics as compared to parents, i.e., high survival rate, fast growth and attractive appearance. Productivity in grow-out systems for hybrid carps increased by 50-100% compared to pure local varieties in traditional grow-out system. Unfortunately, due to improper breeding management, the base stocks of common carp are gradually losing their purity, thus decreasing the effectiveness of crossing for hybrids.

Selective breeding of common carp

The research programs for selective breeding of common carp in Vietnam were initiated in 1981 and included three phases. In the first phase (1981-1985), the program focused on the assessment of initial stocks for selection. To bring together a number of positive qualities from different varieties and to improve genetic variability, the Vietnamese white carp, the Hungarian scale carp and the Indonesian yellow carp were crossed. The three double hybrid stocks were used as the base population for further mass selection. In the second phase of the program (1986-1995) mass individual selection has been carried out among these hybrid stocks over six generations. Determination of the realized heritability of body weight showed that after five selected generations the effectiveness of selection for growth rate of marketable fish was relatively high: growth of the fish increased by 33% (Thien 1996). In the third phase (1996-2005) further improvement of growth rate of selected stocks has to be realized by family selection. Assessment of progeny of nine families which were obtained in the same day is underway. On the other hand, the program for dissemination and evaluation of improved common carp was started in 1996. For two years (1996-1997) more than 40 million larvae, fry and fingerlings have been distributed to the fish farmers for assessment. According to the preliminary information, on-farm trials have almost been successful.

Selective breeding of silver carp

The first step in silver carp selection program aimed to restore the pure stocks of two species: Vietnamese silver carp *(H. harmandi)* and Chinese silver carp *(H. molitrix)*. The second step of the selective breeding program was to improve the purity and genetic quality of the identified stocks. Unfortunately, for the last few years, interest of fish farmers in raising silver carp has been gradually declining because of low market price.

Selective breeding of mrigal

A breeding plan for mrigal in Vietnam based on individual selection to improve growth rate has been prepared. Progress is rather slow for several reasons. First of all, it is considered that the role of mrigal in aquaculture in Vietnam has to be assessed more carefully. Since 1996, the data on mrigal production and socio-economic impact of mrigal culture in the north have been collected. On the other hand, it was noted in the work plan that before carrying out the breeding program, a base mrigal population should be upgraded to broaden the genetic base and eliminate inbreeding. To acquire wild mrigal, 50 fingerlings of mrigal collected from river were introduced in Vietnam from CIFA, India in January 1997. Up to date, the mean body weight of the new mrigal strain is around 200 gram and possibly they will mature in 1998.

A breeding program of silver barb has been prepared by the experts of AKVAFORSK, RIA 2 and ICLARM. Hopefully that this program will be initiated soon.

3. CARP CULTURE AND FUTURE RESEARCH

Carps including indigenous and exotic species play an important role in freshwater aquaculture in Vietnam especially in the northern region where these species contribute around 90% of finfish production in inland aquaculture. Yearly, carp seed production is about 4-5 billion larvae, fry and fingerlings. This quantity fully meets the demand of fish farmers. However, the problem in increasing freshwater fish production is the low genetic quality of cultured species. Improvement of genetic quality of carp species is crucial issue and needs to be addressed by Research Institutes of Aquaculture. At present, aquaculture genetics research is weak in these Institutions. The selective breeding programs for common carp, mrigal and silver barb for growth rate and possibly selection of grass carp towards improvement of disease resistance are our research priorities in coming years.

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CURRENT STATUS OF CARP GENETICS RESEARCH AND BREEDING PRACTICES IN THE MEKONG DELTA - VIETNAM

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1. INTRODUCTION

Mekong Delta has high potential for aquaculture development. The total surface area is about 4 million ha including 195,000 ha of mangrove forest, 290,000 ha of melaleuca forest and 248,000 ha of natural water bodies (Xuan, 1992).

In the dry season (November - April) the saline intrusion reaches 20 - 60 km inland. As a consequence, 50% of the total surface area is affected by the saline water and insufficient freshwater. By contrast, in the wet season (May - October) all the Mekong Delta area is flooded to a depth of 0.3m to over 2m.

The Mekong Delta is the most important region for fish production in Vietnam. The potential water surface area for fish production is 1,383,838 ha, comprising small ponds (4.4%), lowland areas (39.5%), large water surfaces (28.5%) and littoral lagoons (27.9%) (Thuoc et al. 1995). Although vast aquatic resources are available for aquaculture in the Mekong Delta, presently, only less than one third of the suitable area is used for aquaculture. Only 10% of the 320,000 ha rice land is used in integration with fish and prawn (Tuan et al. 1995).

2. CURRENT STATUS OF AQUACULTURE IN THE MEKONG DELTA

The Mekong Delta is a major producer of fish in Vietnam, providing approximately 48% of the national annual fish production (MRC,1992). Annual fish production (including shrimp and prawns) from Mekong Delta in 1991 was estimated at 480,000 tons, of which 46,000 tons was derived from freshwater capture fishery (9.6%) and 116,000 tons from freshwater aquaculture (Jensen, 1994).

Area and population of Mekong river Delta were accounted for approximately 12% and 22% of the national area and population, respectively. About 80% of the population in the delta live in the rural area. Therefore, agriculture including aquaculture plays an important role. To obtain an annual growth rate of 10% of aquaculture production, freshwater aquaculture, especially small-scale fish farms should be given more consideration in the region (Ministry of fisheries, 1996).

In Mekong Delta there are 255 freshwater fish species, belong to 43 families and 130 genera, of which 55 species are economically important Mai Dinh Yen and Nguyen Van Trong (1985). Of them, 83 species (32.5%) belong to Cyprinidae family.

A total of 24 freshwater species are being cultured in the delta, of which 12 species are indigenous and 12 exotic. Silver barb *(Puntius gonionotus)* is currently one of the most popular species in the region, but there are indications that exotic carps have greater market potential than indigenous carps.

The major species cultured in the Mekong Delta region are: common carp, silver barb, tilapia, silver carp, prawn, indian carp, catfish and others (snakehead, climbing perch, gourami, etc.).

In the Mekong Delta seed production has developed quickly in recent times. There were very few hatcheries in 1975. By 1996, there were 39 hatcheries producing 5,000 million larvae, 542.1 million fingerlings (Long et al., 1996). Among the produced seed, common carp, silver barb and silver carp occupy over 50%. In the eight provinces of Mekong Delta where the hatcheries are located, Vinhlong, Cantho and Tiengiang produced and consumed over 82.5% of the total fingerling production of Mekong Delta, (Long et al.,1996).

3. CURRENT STATUS OF CARP GENETICS RESEARCH

3.1 Kariotype of some carp species of Mekong Delta

In recent times, about 50 freshwater fish species were investigated for chromosomes (Nga, 1989, 1994; Dung, 1992). Here are some results related to the kariotyping of some carp species of Mekong Delta:

Puntius gonionotus:

- The diploid chromosome number is 2n = 50. The chromosomes can be divided into 4 groups: 4 metacentric pairs (m), 7 submetacentric pairs (sm), 7 subtelocentric pairs (st) and 14 acrocentric pairs (a).
- The number of chromosome arms is NF = 72.
- Formula of karyotype is 8m + 14sm + 14st + 28a. NF = 72 (Nga et al, 1996).

Puntius altus:

- The diploid chromosome number is 2n = 50. The chromosomes can be divided into 4 groups: 5 metacentric pairs (m), 11 submetacentric pairs (sm), 2 subtelocentric pairs (st) and 7 acrocentric pairs (a).
- The number of chromosome arms is NF = 82.
- Formula of karyotype is 10m + 22sm + 4st + 14a. NF = 82 (Nga et al, 1996).

Catla catla

- The diploid chromosome number is 2n = 50. The chromosomes can be divided into 4 groups: 4 metacentric pairs (m), 7 submetacentric pairs (sm), 7 subtelocentric pairs (st) and 7 acrocentric pairs (a).

- The number of chromosome arms is NF = 72.
- Formula of karyotype is 8m + 14sm + 14st + 14a. NF = 72 (Nga et al, 1996).

3.2 Triploid and diploid gynogenesis manipulation:

In 1989 - 1990 some experiments were conducted for triploid manipulation of common carp in cooperation with the Russian expert in Thu Duc Fish Farm (RIA2). And also in 1994 - 1995 in Cai Be Research Centre (in cooperation with the Vietnamese experts of Russian - Vietnamese Tropical Research Centre). Some preliminary results were observed from these experiments.

In 1997, with one project funded by Ministry of Fisheries, RIA2 carried out one trial on the diploid gynogenesis of Silver barb in Caibe Research Centre.

4. FUTURE RESEARCH NEEDED

4.1 Breeding plans for stock improvement of Silver barb (*Puntius gonionotus*)

Land races of Silver barb will be collected from different river systems of Mekong Delta. These wild stocks will be screened by investigating differences in intrinsic and extrinsic genetic traits by means of electrophoresis, morphological and growth rate. Two or more lines of Silver barb through conventional methods will be established by unrelated crossing. The breeding program will be set up by mass selection and family selection to get the genetic improvement of Silver barb in the future.

4.2 Stock improvement of Common carp (*Cyprinus carpio* L.) in cooperation with RIA1.

4.3 Gynogenesis and sex-reversal of Silver barb (*Puntius gonionotus*):

- Using chromosome manipulation technique to produce meiotic gynogens
- Using androgen hormones to produce neomales
- Using normal female mated by neomales to produce all female.

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ANNEX 3

Socioeconomic Issues Related to Carp Industry in Participating Countries

CURRENT STATUS OF INLAND CULTURE FISHERIES OF BANGLADESH WITH SPECIAL REFERENCE TO POND AQUACULTURE

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Bangladesh is basically an agrarian economy. Fisheries, as a component of agriculture, plays an important role in nutrition, employment and foreign exchange earning of the economy. About 80 % of the national animal protein intake, 5 % of the GDP and more than 12 % of the export earnings comes from fisheries. As an economic activity, fisheries rank second to agriculture, providing livelihood to about 1.4 million people and livelihood support to over 11 million part-time fishermen.

From the view point of fish production and management, fisheries can be categorized into three broad classifications: 1) inland open waters (rivers, beels, haors, kaptai lake and floodplains); 2) inland closed waters (tanks/*dighis*, ponds, baors and coastal aquaculture); and 3) marine waters. So far, there are about 260 fish species. 12 exotic fish species and 24 species of shrimps identified in freshwater: while there are about 475 species of fish and 36 species of shrimps in the marine water (Ali and Hossain, 1996).

Total fish production comes from 4.05 million ha of inland open waters, 0.29 million ha of inland closed waters and 1.66 lakh sq. km of marine waters. The present water areas and total fish production is presented in Table 1.

Table 1: Water areas and total fish production in Bangladesh, 1994/95

Fisheries sector	Water area (ha)	Total production (mt)	Share (%)
Inland fisheries			
a. Capture (open waters)			
River and estuaries	1,031,563	152,782	
Sundarban		6,951	
Beels	114,161	58,298	
Kaptai Lake	68,800	5,556	
Floodplains	2,832,792	367,558	
Total	4,047,316	591,145	50
b. Culture (closed waters)			
Ponds	146,890	267,282	
Baors	5,488	2,460	
Shrimp farms	137,996	47,331	
Total	290,374	317,073	27
Marine fisheries			
a. Industrial fisheries		11,715	
b. Artisanal fisheries		252,935	
Total		264,650	23
Country total		1,172,868	100

Source: Fish Catch Statistics, 1994/95 (DOF, 1997)

As shown in Table 1, the country's total fish production was estimated at 1.17 million mt of which 77 % was from inland (capture in open waters, 50%; culture in closed waters, 27%) and 23% from marine fisheries. Though inland open water capture fisheries is the major source of fish production, its shares is generally on the decline, while that of inland closed water culture fisheries (aquaculture) is on the rise over the years (Table 2).

Table 2: Growth rate of production from inland fisheries in Bangladesh, 1983/84-1993/94

Inland fisheries	Growth rates
Capture (open waters)	
River and estuaries	-4.43
Sundarban	-0.49
Beels	1.08
Kaptai Lake	5.54
Floodplains	6.63
Culture (closed waters)	
Ponds	7.62
Baors	9.01
Shrimp farms	12.63

Although aquaculture is growing very fast, its average yield is comparatively lower than most of the other countries in Asia (Table 3).

Table 3: Average yield of aquaculture under different environments in Bangladesh, 1986/87-1994/95

Inland culture	**Average yield (kg/ha/year)**					
	1986/87	**1987/88**	**1988/89**	**1989/90**	**1992/93**	**1994/95**
Ponds	973	1,017	1,055	1,376	1,515	1,820
Baors	214	228	241	329	401	448
Shrimp farms	253	269	251	312	286	343

POND AQUACULTURE

Fish production from ponds is the most important component of fishery sector as there are 1.3 million ponds with a total area of 147,000 ha. Fish farmers are operating an average of 0.11 ha of fishponds. The ponds are classified as: 1) cultured (where fish are stocked); 2) culturable (where fish come naturally, not stocked); and 3) derelict (not suitable for fish culture). The distribution of these ponds and their production are shown in Table 4. As expected, most of the total fish production from ponds comes from cultured ponds (79 %) and it has comparatively higher productivity (2,759 kg/ha/yr) than the other types of ponds.

Table 4: Different types of ponds and their fish production in Bangladesh, 1994/95

Type	**% of pond**	**% of area**	**% share to pond production**	**Yield (kg/ha/yr)**
Cultured	46	52	79	2,759
Culturable	30	31	16	950
Derelict	24	17	5	515
All ponds	100	100	100	1,819

Among the 19 regions (old districts) of Bangladesh, Comilla, Chittagong, Rajshahi, Noakhali, Mymensingh, Dinajpur and Jessore are the leading regions in fish production from ponds. The details of the annual total production of inland fisheries and fish production by region is presented in Table 5.

Table 5: Annual fish production of inland fisheries by district in Bangladesh, 1994/95

Region/Old District	Pond	Total
Chittagong and CHT	27,110	71,179
Comilla	32,598	99,729
Noakhali	23,442	73,840
Sylbet	9,781	66,066
Dhaka	9,004	38,867
Faridpur	11,102	42,485
Jamalpur	1,275	9,213
Mymensingh	21,083	132,680
Tangail	3,095	8,398
Barisal	13,821	64,112
Jessore	18,305	42,705
Khulna	11,193	70,711
Kushtia	2,222	7,358
Patuakhali	14,647	30,401
Bogra	10,797	15,385
Dinajpur	20,715	25,658
Pabna	8,601	19,166
Rajshahi	24,174	62,301
Rangpur	4,307	27,964

Carp Production

Carps are the most popular and important freshwater species being cultured in ponds. Fish farmers are rearing three groups of carp: 1) major carp (rohu, catla and mrigal); 2) exotic carp (silver carp, common carp, mirror carp and grass carp); and 3) other carps (ghania, kalbasu and kalia). Together, they constitute about 26% of the total inland production and about 76% of the fishpond production. Over the years, the share of carp to total fish production is increasing as shown in Table 6.

Table 6: Share of carp total fish production in Bangladesh (1986/87-1994/95)

Year	Major carp	Exotic carp	Other carp	All carp species
1986/87	10.88	1.44	1.28	13.60
1987/88	10.68	1.00	0.60	12.28
1988/89	12.20	1.50	1.45	15.15
1989/90	12.11	1.98	1.69	15.78
1990/91	13.41	2.77	1.84	18.02
1991/92	14.81	3.17	1.04	19.02
1992/93	14.19	3.07	0.86	18.12
1993/94	15.04	4.40	1.04	20.48
1994/95	14.82	4.68	0.89	20.39

As the aquaculture production expands, the percentage share of carp species production is expected to increase. The government is putting considerable effort and resources to promote carp polyculture which will allow these species to further dominate the freshwater aquaculture production in the near future.

SPECIES COMPOSITION IN FISHPOND PRODUCTION AND PREFERENCE

Fish farmers' preference in culturing different carp species in ponds is shown in Table 7. About 93 % of all species reared in "cultured" ponds are carps. But, this is the other way around for the "culturable" and "derelict" ponds. Overall, carps account for about 77 % of all fish species reared in ponds.

Table 7: Species composition (% of weight) by status of ponds in Bangladesh, 1994/95

Species	Cultured ponds	Culturable ponds	Derelict ponds	All ponds
All carp species	92.98	22.19	13.61	76.40
Rohu	31.83	5.55	1.76	25.65
Catla	22.69	7.97	3.92	19.11
Mrigal	13.81	4.34	3.85	11.66
Kalbasu	2.80	0.51	0.22	1.79
Mixed carp	5.30	0.91	1.12	4.33
Silver carp	13.56	2.78	2.60	11.12
Grass carp	1.66	0.05	0.13	1.30
Mirror carp	1.33	0.08	0.01	1.04
Other fish species	7.02	77.81	86.39	22.60
Total	100	100	100	100

Among the different carp species, rohu, catla and mrigal are the top preferred species. They comprised the major species reared in ponds. This preference bias is mainly due to the taste of the species from the buyers' point of view and their relatively high market prices from the sellers' point of view. In surveying the market intermediaries, Alam (1995) also observed similar findings. In addition, Rahman and Ali (1986) found that most farmers practice polyculture of rohu, catla and mrigal. Also, Islam and Dewan (1987) found that the major fish species cultured by fish farmers were rohu (98 %), catla (93 %), mrigal (49 %) and silver carps (41 %). Furthermore, about 43 % of them practiced polyculture of rohu, catla and mrigal and only about 25 % practiced polyculture of rohu, catla, mrigal and silver carp.

TECHNOLOGY PREFERENCE

Given the choice of species to raise in fishponds, fish farmers will be opting for major carps. This is mainly because of the consumers' taste preference, the opportunity to get better price and the social prestige it showered to pond owners for raising only major carps. The values and the culture systems, however, have undergone a major change with the efforts of the Fisheries Research Institute, ICLARM and NGO to promote polyculture for maximum utilization of pond productivity. Polyculture is now widely accepted with rohu, catla, mrigal, silver carp, mirror carp, grass carp, kalbasu and shorpunti (silver barb) as the widely used fish species. Monoculture is hardly practiced. Those following it are either raising rohu or catla. Tilapia is of recent interest to fish farmers although it requires minimum cost and care.

Fish farmers' attitude concerning input use has also undergone a major change. It is now easier to convince them to use the necessary inputs (e.g., cow dung, urea and compost) in their pond operations as compared to few years back. Most of them are very receptive to production technologies recommended by government research institutes and the NGOs working for aquaculture development in the country.

SOCIOECONOMIC CHARACTERISTICS OF CARP FARMERS

Carp farmers are having an average of 25 decimals of homestead, 5 decimals of orchard/forest, 3 decimals of fallow land and 30 decimals of pond under their disposal. The value of their asset is ranging fromTk 33202 to Tk 48117. Farmers' income from fish farming is only about 7% to 22% of their annual income of Tk 45058 to Tk 67875; only 6% to 16% of carp farmers are reporting fish farming as their main occupation (Resource Management Consultants, 1995). Earlier, Rahman and Ali (1986) found that none of the farmers had fish farming as their main occupation.

INPUT USE, YIELD AND PROFITABILITY OF FISHPOND OPERATION

Fertilizer and feed are the major inputs used in fishpond operation in Bangladesh. Organic fertilizer application varies from 120 kg/ha to 500 kg/ha, while inorganic fertilizer varies from 55 kg/ha to 716 kg/ha. For feed, it varies from 217 kg to 659 kg for oil cake and 58 kg to 504 kg for rice bran (Islam and Dewan, 1987). These wide variations in the use of fertilizers and feeds are major factors affecting fishpond productivity in the country. Dewan et al. (1994) found that the yield of seasonal ponds varied from 1,744 kg/ha to 2,614 kg/ha, while that of perennial ponds varied from 680 kg/ha to 2,879 kg/ha. The results of Resource Management Consultants (1995) showed that the average fish yield varied from 1,482 kg/ha to 3,705 kg/ha.

Fish farming is a very profitable endeavor. The benefit-cost ratio (BCR) of fishpond operation can be considered high as shown in Table 8. However, the total cost, total revenue, net profit, yield (productivity) and BCR of fishpond operations vary substantially among management, cultural practices and location.

Table 8: Costs, returns, profit and benefit-cost ratios (BCR) from pond fish culture in Bangladesh

Author	Yield/ha (kg)	Total revenue (Tk/ha/yr)	Total cost (Tk/ha/yr)	Net profit (Tk/ha/yr)	BCR
Hossain (1996)	5229	145065	83745	61320	1.73
Rahman (1995)					
Netrokona	964	51631	9341	42290	5.52
Purbodhola	935	46659	11844	34815	3.94
Kendua	935	51420	11631	39789	4.42
All locations	943	49515	10103	39412	4.90
Islam & Dewan (1987)					
Gouripur	2264	49992	11757	38235	4.25
Mymensingh	1700	45420	11542	33879	3.94
Gazipur	2039	53426	7165	46261	7.45
Laksmipur	3359	96416	11241	85175	8.58
Jessore (N)	3889	82661	13403	69258	6.16
Jessore (S)	3706	79606	19234	60373	4.14
All locations	2867	69201	12253	56948	5.65
Rahman (1995)					
Inst. mgt.	4745	166172	53880	112292	3.08
Owner mgt.	3577	119200	53307	65893	2.23
NGO mgt.	8446	382923	245443	137480	1.56

A study on some NGOs following ICLARM-FRI technology displayed wide variations in costs, returns, profits and BCRs, as shown in Table 9. These results are consistent with the above findings indicating that fish farming is very profitable but risky. These variations can be attributed to differences in management practices, sizes of ponds, intensity of input use, factor and market prices.

Table 9: Costs, returns, profits and BCR from pond fish culture of selected NGOs in Bangladesh, 1994

	Seasonal Ponds				Perennial Ponds			
Name of NGOs	Total cost	Total revenue	Net profit	BCR	Total cost	Total revenue	Net profit	BCR
RDRS	15789	48269	32480	3.05	17059	54639	37581	3.20
TMSS	46683	83885	37202	1.80	33676	83362	49686	2.47
Uttaran	33490	90108	56618	2.69	35464	104391	68927	2.94
PMUK	54721	43406	10315	-	34764	78056	43292	2.06
BRAC					12209	24682	12473	2.02
J. Chakra					21418	19468	-1950	-
GAT					14374	30913	16534	2.15
U. Shangha					31426	38529	7103	1.22

Source: Dewan et. al (1994)

PRODUCTION CONSTRAINTS

Despite that constraints to aquaculture production have been the subject of research for the last one and a half decades, species-wise studies particularly for carps are not available. Hence, only the social, economic, technical and infrastructural constraints to aquaculture production, especially of fishponds are presented (Table 10).

Table 10: Constraints to aquaculture production in Bangladesh

Nature	Constraint
Social	Fear of thieves, enemies and poisoning
	Lack of proper cooperation of concerned agencies
	Interference of village leaders
	Joint ownership/operatorship of ponds
	Multiple use of ponds interfering fish culture
	Lack of quality seed in adequate quantity
	Problem created by vested interest villagers in getting lease
	Cheating made by the fry-fingerling suppliers in specifying type of species
Economic	Low harvest prices of fish
	High prices of feed and other inputs
	Lack of capital and credit
	Lack of proper markets and marketing facilities
Technical	Sudden breakthrough of diseases and attack of parasites
	Insufficient water in dry season
	High mortality rates of fingerlings
	Difficulty to maintain water quality
	Faulty pond design and sizes
	Limited knowledge of the culturists
	High risks of the pond fish culture
Infrastructural	Inadequate and poor roads and highways
	Inadequate transport and storage facilities
	Absence of central pulling (landing) spots

PRICES OF CARP SPECIES

Rohu, catla, mrigal are the widely preferred carp species. These species are receiving relatively higher farm gate prices than other carp species. Prices of rohu, catla and mrigal ranged from Tk 33-34 /kg while that of exotic species were only Tk 22-24 /kg in 1992. Also, these carp species have prices higher than those of other carp species in 1994 (rohu, Tk 50/kg; catla, Tk 47/kg; mrigal, Tk 45/kg; kalbaso, Tk

45/kg; carpu; Tk 41; mirror carp, Tk 40/kg; grass carp, Tk 37/kg; and silver carp, Tk 34/kg).

At retail market, rohu is also priced higher in comparison with other fish species with high preference as shown in Table 11. Fish prices displayed wide variations. This can be mainly attributed to the differences in the size of fish. Fish prices also displayed spatial differences which can be attributed to differences in marketing and transport costs.

Table 11: Retail prices of selected fish species in Bangladesh (Tk/kg), 1990/91-1994/95

Species	Town	1990/91	1991/92	1992/93	1993/94	1994/95
Rohu (cut piece)	Dhaka	114	118	137	139	140
	Chittagong	93	101	122	133	131
	Rajshahi	104	115	128	138	140
	Khulna	109	122	139	137	141
Hilsa (medium size)	Dhaka	54	62	75	72	85
	Chittagong	38	45	54	64	61
	Rajshahi	45	56	67	63	76
	Khulna	46	50	56	66	76
Koi (medium size)	Dhaka	101	109	126	134	137
	Chittagong	85	93	103	131	136
	Rajshahi	81	83	89	124	135
	Khulna	104	90	97	132	138

FISH CONSUMPTION AND DEMAND FOR CARP

Availability of fish for domestic consumption has stabilized at about 7.5 kg/capita/annum since the late 1970s, according to the Department of Fisheries. But the data from the BBS Household Expenditure Survey indicated that annual per capita fish intake increased from 9.84 kg/capita in 1973/74 to 12.99 kg/capita in 1985/86. The annual fish per capita consumption is higher in urban (16.46 kg) than in rural areas (12.55 kg) and as income increases, consumption of fish also increases (Table 12). This high responsiveness of fish consumption to changes in incomes is reflected in the highly elastic income elasticity of demand for fish ranging from 0.96-1.03.

Table 12: Annual per capita fish consumption in Bangladesh, 1985/86

Household monthly income (Tk)	Annual per capita fish consumption (kg)		
	Rural	Urban	Total
<500	4.37	4.70	4.37
500 - 749	6.61	6.05	6.61
750 - 999	7.94	7.73	7.83
1,000 - 1,249	8.51	10.31	8.62
1,250 - 1,499	10.07	12.43	10.18
1,500 - 1,999	11.42	12.21	11.54
2,000 - 2,499	12.88	14.00	12.99
2,500 - 2,999	13.11	15.46	13.44
3,000 - 3,999	13.88	16.12	14.11
4,000 - 4,999	15.46	18.02	16.35
5,000 - 5,999	14.79	20.04	16.02
6,000 - 6,999	19.58	20.04	19.70
7,000 - 7,999	20.15	21.60	20.69
>8,000	21.70	22.17	21.95
Average	12.55	16.46	12.99

Source: BBS (1988)

No study yet has been undertaken to estimate the income or price elasticity of demand for specific species like carps. The overall demand for domestic consumption is projected to increase from the present level of 0.8 million mt to 1.8 million mt in year 2009-10. The gap between the supply and demand is projected to be 33% for the slow growth scenario and 13% for the moderate growth scenario (World Bank, 1991).

SOCIOECONOMICS RESEARCH ON CARPS AND FUTURE RESEARCH NEEDS

Despite the involvement of several government, non-government, and international organizations on carp research, socioeconomic studies on carp species has not yet been given priority. Even economic studies on consumption pattern of fish in general, species preference and their market potentials have been greatly bypassed.

Some of the research needs for the development of aquaculture, in general, and carp farming industry, in particular, may include: 1) assessment of production technologies prior to its promotion and diffusion; 2) determination of optimum input application, pond size, depth of pond, etc. under different environments, culture systems and socioeconomic status of fish farmers; and 3) market studies, consumption patterns, price and demand analysis.

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SOCIOECONOMIC ISSUES RELATED TO CARP INDUSTRY IN CHINA

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China has longest history of freshwater aquaculture in the world that dates back to 5 B.C. Due to strong government policy to promote fisheries development coupled with increasing demand for fish and other aquatic products have resulted to rapid development not only of the freshwater aquaculture but also of the fisheries sector as a whole. The fisheries industry has been growing tremendously since the start of 1980s. By 1996, the national production of aquatic products reached over 28 million mt in China, a production record way far ahead of other countries in the world. Table 1 shows the 1995 fish production from freshwater fisheries and its contribution to the total production of the fishery sector in China.

Table 1: National fisheries production in China 1995 (thousand tons)

Item	Fishery sector	Freshwater		
		Aquaculture	Capture	Total
Production	25,171.8	9,407.6	1,372.9	10,780.5
% contribution	100	37.37	5.45	42.83

Freshwater fish production is becoming a major source of fishery production. It accounted for about 43% of the total production of the fishery sector. This can be attributed to the rapid development of freshwater fish culture and depletion of natural fish resources in the country. In 1995, total freshwater fish production reached 10.78 million mt, in which bulk of production came from aquaculture (87 %) than from capture fisheries (13 %).

There are more than 800 different freshwater fish species identified in China. Majority of these or 50% are species of carps. Also, majority of the economically important freshwater fish species are carps. Even in the freshwater capture fisheries, carp species are estimated to comprise about 80-90% of the total fish catch. Hence, carps are the most important freshwater species despite the introduction of several exotic species to different aquaculture systems in the country. Currently, 8 out of the more 10 major carp species being cultured are of national socioeconomic importance, namely: black carp (*Mylopharyngodon piceus*), grass carp (*Ctenopharyngodon iolellus*), common carp (*Cyprinus carpio*), silver carp (*Hypophthalmichthys molitrix*), bighead (*Aristichthys nobilis*), crucian carp (*Carassias auratus*), and Chinese bream (*Megalobrama amblycephala* and *Parabramis pekinesis*). Production of this 8 species reached nearly 9 million tons in

1995 and together accounted for about 95 % of the total freshwater aquaculture production (Table 2).

Table 2: National production of major carp species from aquaculture in China, 1995 (thousand tons)

Item	Black carp	Grass carp	Silver carp/ Bighead	Common carp	Crucian carp	Chinese bream	Total
Production	102.6	2,071.0	3,713.3	1,398.6	533.7	335.9	8,970.4

China is country with vast territory, different natural environments and socioeconomic conditions. The aquaculture industry is in various stages of development. The geographic distribution of different carp species is also very uneven. These variations can be attributed to differences in the levels of aquaculture development, climatic conditions and social-cultural traditions. Carp production is mainly concentrated in southern and eastern parts of China, especially the middle and lower reaches of the four major river systems: Yangtse River, Pearl River, Yellow River and Heilong River. Among the major cultured species, silver carp, bighead, common carp and crucian carp are relatively evenly distributed all around the country. Grass carp and Chinese bream are mainly raised in the south-eastern part of China. While, black carp is mainly cultured in the middle and lower reaches of Yangtse River and Pearl River. Table 3 gives the geographic distribution and production of major carp species being cultured.

Table 3: Geographic distribution the production of major cultured carp species (thousand tons), 1995

Region	Grass carp	Black carp	Common carp	Crucian carp	Silver carp/ Bighead	Chinese bream	Total
Central east	897.03	73.29	504.18	345.31	1,954.35	263.92	4,038.08
South east	956.41	29.11	336.90	111.90	1,246.84	68.51	2,749.67
North east	69.32	0.02	361.89	39.65	310.36	2.56	783.80
South west	133.36	0.15	143.03	30.73	155.07	0.43	462.77
North west	14.87	0.00	52.62	6.15	46.65	0.51	120.80
Total	2,070.99	102.57	1,398.62	533.74	3,713.27	335.93	8155.12

CARP CULTURE SYSTEMS

Various production systems have been developed for the culture of carps. Most of the culture systems are based on polyculture of different carps and other species. Polyculture is still the dominant carp culture system. However, monoculture is becoming popular for very intensive carp culture in cage, pond and running water systems. The major carp culture systems, stocking pattern and culture intensity are given in Table 4.

Table 4: Major carp culture systems in China

Systems	Pond culture	Cage culture	Pen Culture	Lake/reservoir
Pattern of stocking	Monoculture (common carp, crucian carp)/ Polyculture	Monoculture (common carp)/ Polyculture	Polyculture	Polyculture
Culture intensity	Intensive /Extensive	Intensive /Extensive	Intensive /Extensive	Extensive

Species composition of different polyculture systems is rather complicated. Stocking formula of carp varies with regions, culture intensity, farming practices and many other factors. Even at the same farm, there can be different stocking formula for the same culture system.The stocking formula is also subject to changes in demands. Thus, species composition of different polyculture systems in China can only be generally summarized as in Table 5.

Table 5: Species composition of different polyculture systems in China

Culture system	Intensity	Grass carp/ Chinese bream	Silver carp/ Bighead	Common carp/ Crucian carp	Black carp
Pond Culture	Intensive	50-70%	20-40%	10-15%	0-5%
	Extensive	30-50%	40-60%	10-15%	0-5%
Cage culture	Intensive	60-80%	10-20%	10-20%	
	Extensive	10-20%	60-80%	10-20%	
Lake/Reservoir	Extensive	10-20%	60-80%	10-15%	0-5%

GENERAL CHARACTERISTICS OF CARP FARM

There are basically four types of carp farms according to the ownership: state owned, collective, private family-based, and private commercial farm. Farm size is closely related to ownership and culture system. State owned and collective farms are generally larger in size than private farms Recently, however, several private commercial farms are joining the industry as the market oriented economy develops in China. These large private carp commercial farms are usually concentrated in the special economic trade zones of the country resulting to geographic variation in farm size. The normal farm size for carp farming under different culture systems is shown in Table 6.

Table 6: Normal size of carp farms under different types culture systems and ownership in China

Culture system	Ownership	Size range
Pond culture	State owned/collective Family based private Commercial private	10-50 ha. 1-2 ha. 10-30 ha.
Cage culture	State owned/Collective Family based private	1,000-2,000 m^2 10-100 m^2
Lake/Reservoir	State owned/collective	50-2,000 ha.

SOURCES AND INCOME LEVELS OF CARP FARMERS

Income sources of carp farmers greatly depend on their geographical location and on the economic opportunities in the area. In more developed area, income of fish farmers consist of fish production, small industry (such as processing and culture related), and commercial activities, such as restaurant and tourism. But in less developed rural area, income of carp farmers comes mainly from fish production, agriculture and animal husbandry.

It is very difficult to have precise income data of fish farmers especially carp farmers. Generally, income of carp farmers is substantially affected by their farming intensity, the local economic development in their area, market demand and fish prices. Comparatively, income level of fish farmers is higher than ordinary farmers. In some areas, it is even higher than the income of factory workers. In 1995, the average annual per capita income of fish farmers and fishermen was 3,352 Yuan and 6,642 Yuan, respectively. While, average annual per capita income of agricultural population was only 1,580 Yuan for the same year. Table 7. shows the 1995 average annual per capita income of fish farmers and fishermen in different regions.

Table 7: Average income of fishermen (majority are farmers) in different areas of China 1995 (in RMB yuan)

Province/ Region	Annual income per head	Annual income per labor	Province/ Region	Annual income per head	Annual income per labor
Zhejiang	4,768	10,847	Heilongjiang	3,183	6,828
Guangdong	4,210	9,730	Guangxi	2,855	5,995
Shanghai	5,250	8,638	Beijing	3,450	5,500
Tianjing	4,234	8,540	Hunan	2,621	5,461
Liaoning	4,150	8,275	Hubei	1,800	3,420
Hainan	3,755	7,911	Jiangxi	2,071	3,164
Shandong	3,900	7,743	Shanxi	2,071	3,164
Fujian	3,198	7,427	Henan	2,143	3,164
Hebei	3,553	7,290	Sichuang	1,274	2,174

Input Use by Culture System

Inputs for carp culture are mostly dependent on culture system and production level. Production cost of intensive culture system is generally higher than the extensive system and increases along with production levels. Feed, seed and labor are the major inputs in carp farming. Table 8 gives the normal composition of production cost in different carp culture systems.

Table 8: Composition of production cost in different carp culture system

Culture system	Intensity	Feed	Seed	Labor	Fertilizer	Other
Pond	Intensive	35.2%	26.4%	22.1%	1.6%	14.7%
	Extensive	31.5%	27%	20.9%	6%	14.6%
Cage	Intensive	35%	26%	18%		21%
	Extensive	15%	60%			25%
Pen	Intensive	35%	25%	20%		20%
	Extensive	30%	30%	20%		20%

Experimental Station Yield by Culture System and Species

There have been various experiments to determine carp yield in different culture systems. The followings are some of the "best" or highest yield attainable for the different culture systems:

1) Pond culture: 38 t/ha;
2) Cage culture: 2,973 t/ha
3) Pen culture: 75 t/ha.
4) Lake/Reservoir: 2 t/ha.

It is quite difficult to separate the yield of different species under polyculture system. Experimental yield of various carp species, shown in Table 9 were derived by adjusting results obtained from various experiments.

Table 9: Experimental yield of some carp species (high level) in China

Species	Yield	Culture system
Silver carp & Bighead	245 t/ha	Polyculture in cage
	6 t/ha	Polyculture in pond
Common carp	15 t/ha	Monoculture in pond
	2,973 t/ha	Monoculture in cage
Grass carp & Chinese bream	50 t/ha	Polyculture in cage
	50 t/ha	Polyculture in pond
Black carp	5 t/ha	Polyculture in pond

FARM-LEVEL YIELD BY CULTURE SYSTEM AND SPECIES

As China is a very large country with different natural environmental conditions and development levels of carp culture, farm-level yield of carp varies greatly. Generally, yield is relatively higher in the areas with long history (traditional practice) of carp culture. Farm level yield of different culture systems and different carp species in pond are given in Tables 10 and 11. Yield in pen culture is more or less the same as with pond culture. While the yield performance of different carp species is greatly affected by the intensity of culture.

Table 10: Farm level yields of different culture systems in China

Culture system	Pond	Cage	Pen	Lake/Reservoir *
Low	<2,000 kg/ha.	<5 kg/m^2	<2,000 kg/ha.	<200 kg/ha.
High	15,000 kg/ha.	100-200 kg/m^2	12,000 kg/ha.	2,000 kg/ha
Normal	7,500 kg/ha.	20-50 kg/m^2	7,500 kg/ha.	750 kg/ha.

*--Extensive culture in lake and reservoir with size ranging from 30 ha. to 2,000 ha.

Table 11: Farm level yields of some carp species through polyculture in pond (kg/ha.)

Culture intensity	Grass carp	Silver carp	Bighead	Black carp	Common carp/ Crucian carp	Chinese bream
Extensive	1,000	1,700	425	3	400	238
Medium	1,468	2,400	632	53	600	512
Intensive	2,444	2,900	816	513	1,000	1,766
Maximum	4,000	4,500	1,000	4,500	3,000	1,200

COST, RETURN, AND PROFITABILITY OF CARP FARMING

Profitability of carp farming is considerably determined by culture system and culture intensity. Intensive culture systems are characterized by high input and high output. Profit is usually higher in intensive culture system per unit of water surface area. Comparatively, higher profit can be obtained in cage and pen fish cultures than in pond fish culture. Production cost, gross return and profit of pond and pen cultures of carp are given in Tables 12 and 13, respectively.

Table 12: Production cost, return and net profit of different pond culture practices ($\$ha^{-1}$ year $^{-1}$)

Intensity	Cost	Gross return	Profit
Intensive	2,267.25	3,275.88	1,008.63
Medium	1278.50	1609.75	331.25
Extensive	750.75	1,274.25	523.50

Table 13: Production cost, return and gross profit from different pen culture practices ($ ha^{-1} $year^{-1}$)*

Production level (kg/ha)	Cost **	Return	Profit
5,300	2,750	5,008	2,258
10,000	5,372	9,238	3,866
13,000	7,505	13,749	6,244

*---Grass carp and Chinese bream accounted 70-80% of the production
**--including labour cost

CARP FARMING PRODUCTION CONSTRAINTS

Carp culture has reached a very high level of production per unit area of water surface. To further increase its yield is constrained by many factors:

1. Biotic constraints

Disease problem is a major constraint to higher yield in carp culture. Currently, carp culture is troubled by various fish diseases, mainly infectious diseases, such as virus, bacterial disease and parasites. Increasing the culture intensity for higher yield will intensify these problems. Besides, chemical treatments are very costly and becoming less effective in controlling the spread of diseases.

2. Environmental constraints

Currently, carp culture is seriously affected by environmental problems. The deterioration of natural environment is affecting the production efficiency and increasing the risk of the industry. On the other hand, intensive culture of carp causes environmental problems under certain circumstances. All these have considerable impact on the long term development of the carp industry. Seasonal changes of temperature significantly limits the growth rate of the fish and its yield performance.

3. Socioeconomic constraints

With the current culture techniques, it is still possible to increase carp production per unit area of water surface. But, as it will necessitate the use of more inputs, many farmers, particularly the resource poor farmers, will not adopt the system. Besides, as people's living standard improves, poor quality species such as silver carp and bighead are less preferred by people in some parts of the country. This will affect negatively the effort to further increase the yield of these carp species.

PRICES OF CARP SPECIES

Before the 1980s, fish prices in China were strictly controlled by the government. Hence, there was no seasonal fluctuation and spatial differentials in fish prices at that time. Recently, due to economic reform that led to the development of market-oriented economy, prices of fish have exhibited some instabilities. Prices now depend on the balance between the demand and supply of fish products. In general, prices of carp species are relatively higher in more developed areas of the country. Table 14 gives the normal market price of important carp species. Carp prices decline considerably in early winter (November/ December), as bulk of carp production is marketed during that period.

Table 14: Price range of different carp species in China (US dollar/kg)

Species	Black carp	Common carp	Crucian carp	Chinese bream	Grass carp	Bighead	Silver carp
High	2.5	2.2	2.5	2.0	1.2	1.3	0.9
Low	1.5	0.8	1.0	1.2	0.8	0.8	0.6
Average	1.8	1.0	1.8	1.5	1.0	1.0	0.7

DEMAND FOR CARP

1. Consumption by income group

Generally, carp species are not highly priced fish. The fish are affordable to different income groups. However, there are differences in market prices among the carp species mainly due to meat quality. Better quality species i.e., black carp, crucian carp and Chinese bream, are consumed by higher income groups. While, poor quality species like silver carp and bighead are consumed by lower income groups. Consumption of different species by income groups is sometimes determined by local custom of the people. For instance, common carp is considered as a high quality fish in northern and south-western parts of China, but it is not so preferred by the people in other areas. For crucian carp, it is almost the opposite.

2. Price and income elasticity of demand

Undoubtedly, price has significant impact on the demand for carps. The magnitude of changes in demand due to changes in prices (price elasticity), however, is not available yet for specific carp species. Generally, demand for carp increases as income of people increases. As in price elasticity of demand, there is no study yet that determines the income elasticity of demand for carps in China.

3. Future demand for carp

Although China has the highest fisheries production in the world, the annual average per capita consumption of fishery products in the country (14 kg) is only slightly higher than the world's average (13 kg). This is partly due to its large population. As the living standard of the people improves and with the increasing perception that fish is a much better animal protein food, it is expected that fish demand including that of carps will also increase. However, the increase in demand will not be the same for all carp species. In the areas with faster economic development, demand for better quality species, such as black carp, crucian carp and Chinese bream will increase significantly. While, demand for poor quality species such as silver carp may not increase, but may even decrease in these areas. But in less developed areas wherein people are traditionally consuming less fish, the demand for all carp species can be expected to increase significantly in the future.

EXISTING RESEARCH ON SOCIOECONOMICS OF CARP CULTURE

1. Institutions involved

There are several institutions involved in the socioeconomic research of carp culture in China. The four institutions of national importance are:

a) Fisheries economy research institute, Chinese Academy of Fishery Science;
b) Freshwater Fisheries Research Centre, Chinese Academy of Fishery Science;
c) College of Economic Management , Shanghai Fisheries University; and
d) Department of Management, Dalian Fisheries College.

2. Research status and results

Since 1980s, there have been many socioeconomic research on fisheries in China. Significant research results were achieved and the following are some of national importance:

a) Investigation and study on optimal economic efficiency of pond fish culture (1988)
(Second class prize of Scientific and technological award from the academy);
b) Economic issues related to utilization and development of fisheries resource in China (1988)
(Second class prize of Scientific and technological award from the Ministry);
c) Comparative study of utilization and development of fisheries resource in China (1994)
(Third class prize of Scientific and technological award from the Ministry); and
d) Study on economic structure of comprehensive high yielding techniques in medium sized lake with abundant aquatic weeds. (1996)
(Second class prize of Scientific and technological award from the Ministry)

3. Publications on fisheries socioeconomics

The following are some of the important socioeconomic publications on fisheries in China:

a) Economic issues related to utilization and development of fisheries resource in China. Marine Press, Beijing, 1987
b) General introduction to fisheries ecological economics. Marine Press, Beijing, 1989
c) Economic comparison of fisheries resource. Marine Press, Beijing, 1993
d) Technical economics of fisheries. Chinese Press of Science and Technology, Beijing, 1995
e) The social-economic evaluation and sustainable conservation of local fish strains in China. *Fisheries economic research*, 3, 1994; Fourth Asian Fisheries Forum
f) Chinese integrated fish farming: a comparative bio-economic analysis. *Aquaculture Research*, 26, p.81-94, 1995

FUTURE RESEARCH NEED

In the past, fisheries economic studies were focused on bio-economics and technical aspects of different culture systems in specific region of the country. There were only few studies on the socioeconomic aspects of carp culture, a major component of the freshwater aquaculture industry. Due to its importance, greater efforts need to be exerted to research on socioeconomics of carp culture, especially under the context of developing a market-oriented economy. The following aspects should be the major focal points for future socioeconomic research:

1. Factors affecting the development of carp industry and its socioeconomic impact

In the past, economic studies on carp farming were mainly concentrated on determining the economic viability and production efficiency of the different culture systems. There were limited studies on the socioeconomic factors affecting the development of carp industry and its impact on the economy. Studies on these aspects will be significant in the formulation of policies for the development carp culture industry in China.

2. Environmental-economies of carp culture

Environmental issues related to carp culture are now of significance interest arising mainly from the complexity of relationship between carp culture development and degradation of environment. Full assessment of the environmental cost of different carp culture systems is crucial to the long term sustainable development of the industry.

3. Comparative economic study of carp culture systems

Comparative economic studies were conducted mainly for specific culture system in certain area of the country in the past. Its significance to the national development of carp industry is very limited. The comparative socioeconomic study of different carp culture systems in different parts of the country will definitely benefit the national development of carp culture industry in the future.

4. Socioeconomics of carp genetic improvement and biodiversity protection for sustainable development

Socioeconomics of genetic improvement and biodiversity protection of carp have their significance on improving production efficiency and in sustaining the development of carp industry. Studies on socioeconomic impact of genetic improvement and biodiversity protection of carp will be very important to find a way maximizing production efficiency without sacrificing the long term sustainability of the industry.

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SOCIOECONOMIC ISSUES RELATED TO CARP INDUSTRY IN INDIA : SOME RESEARCH DIMENSIONS

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India is endowed with natural resources suitable for aquaculture. It has 8,085 km of coastline, 164,000 km of rivers and canals, 1.97 million ha of reservoirs, 2.2 million ha of ponds and tanks; 1.3 million ha of beels, oxbow lakes and swamps, and 1.4 million ha of brackishwater area. Traditionally, aquaculture has been practised in freshwater and coastal saline waters characterized by low-inputs and low-production systems. However, aquaculture has been slowly but steadily transforming itself into a business activity during the last decade. Aquaculture production increased almost threefold from 511,500 t in 1984 to 1,438,900 t in 1993 (FAO, 1993).

Carp is dominating the freshwater aquaculture in ponds, cages, pens and recirculating system and inland fisheries production in India. Carp production constituted about 44 % of the total inland fishery production of 5.14 million tons in 1996. In aquaculture, however, only carp pond culture has reached commercial level. The rests are under experimentation or rather being operated on a "small" or limited scale. The national productivity of carp culture in ponds has increased from 900 kg/ha/yr in 1984-85 to 2,130 kg/ha/yr in 1994-95. Freshwater carp culture is widespread in West Bengal, Madhya Pradesh, Orissa and Bihar. Area concentration of carp culture is greatest in Kolleru Lake (Alagarswami, 1995). Among its different states, Punjab (4,100 kg/ha/yr), Haryana (3,660 kg/ha/yr) and Andhra Pradesh (3,500 kg/ha/yr) have the highest average productivity, while Meghalaya (700 kg/ha/yr) has the lowest. Consumers' demand is a major factor influencing the choice of species to culture in the country.

The composite carp culture technology and induced breeding of carps are the two pillars for the development of carp industry in India. The composite carp culture technology was developed at the Pond Culture Division of the Central Inland Fisheries Institute (CIFI), Cuttack during the 70s. The standard management practices include preparation of pond, eradication of aquatic weeds, control of predatory and weed fishes, manuring and fertilization, choice of stocking density and size, optimum ratio of different combination of fish species and fish health (Aravindakshan 1996). While, the induced breeding technology was developed as an alternative to collection of carp seeds from the wild. Through induced breeding, quality carp seeds are now available throughout the year in most parts of India.

PROFITABILITY OF CARP FARMING

A brief summary of the economics of the model projects worked out at the Central Institute of Freshwater Aquaculture (CIFA) for composite carp culture technology and induced breeding technology are given in Tables 1 and 2.

Table 1: Economics of composite carp culture (at 1996 price), by system, at CIFA Farm, Bhubaneswar, India

	Extensive System	Semi-intensive	Intensive
Stocking density (no/ha)	6,000	12,000	20,000
Target fish production (kg/ha)	5,000	10,000	15,000
Total variable costs (Rs/ha)	27,900	105,000	174,000
Total costs (Rs/ha)	43,900	150,000	233,000
Total return (Rs/ha)	120,000	240,000	360,000
Net return over variable cost (Rs/ha)	92,000	135,000	186,000
Cost of production per kg of fish produced (Rs/kg)	11.0	18.7	19.4

Source : CIFA

Table 2: Economics of seed production of carps (at 1996 price) through induced breeding at eco-hatchery, by system, at CIFA Farm, Bhubaneswar, India

	Single Time Induced Breeding	Multiple Induced Breeding
Production capacity (million spawn/ha)	60	200
Fixed capital investment (Rs/ha)	380,000	416,000
Total variable cost (Rs/ha)	150,000	290,000
Total cost (Rs/ha)	224,000	365,000
Total return (Rs/ha)	330,000	1,118,000
Net return over variable cost (Rs/ha)	180,000	828,000
Rate of return on fixed capital investment (%)	47%	199%
Total cost of production per million produced (Rs/million)	3733	1825

Source : CIFA

The technology for composite carp culture can be categorized as extensive, semi-intensive or intensive in terms of input usage. As expected, intensive composite carp culture is the most profitable system. While the net farm income per hectare was only about Rs 76,100 for extensive and Rs 90,000 for semi-intensive system, it was about Rs 127,000[1] for the intensive system. Though the cost of production per kg of fish was higher in the intensive system (Rs 19.40) compared to the extensive (Rs 11) and semi-intensive (Rs 18.70), intensification especially those with limited farm area provides an opportunity for fish farmers to increase their farm income.

Operating carp hatchery is more profitable than engaging in its grow-out operation. For a hectare of carp hatchery following a single time induced breeding system, it is possible to produce 60 million of spawns for a gross return of Rs 330,000 and a net farm income of Rs 106,000. With the switch to multiple induced breeding system, 200 million spawns can be produced for a gross return of Rs 1,118,000 and net farm income of Rs 753,000.

The high profitability of carp farming either of grow-out or hatchery operation has lead to the shift in the farming systems from food crops towards aquaculture in India. These changes are very prominent in some states like Andhra Pradesh, Tamil Nadu and Punjab. In these states paddy and wheat fields are being converted into carp culture ponds. For as long as profit or income from carp farming is higher than crop farming, there would be more conversion of crop lands into carp culture ponds. Currently, this has been the major source of growth of the carp industry in India.

EXISTING RESEARCH ON SOCIOECONOMICS OF CARP CULTURE

1. Institutes involved

Three institutes of national importance are involved in aquaculture economics research. These are:

i) Central Institute of Brackishwater Aquaculture (CIBA), Chennai, Tamil Nadu
ii) Fisheries College and Research Institute, Tuticorin, Tamil Nadu
ii) Central Institute of Freshwater Aquaculture, Bhubaneswar, Orissa

2. Current status of the work

(i) Completed research

a) Production economics of carp culture, measurement of technological change, efficiency and sustainability and estimation of production function and returns to scale

Jhingran and Sharma (1980) explained the importance of integrated livestock fish farming over intensive fish culture in India. The total return, net profit and percentage of net profit to total variable costs were worked out to be Rs 11593, 5729 and 98 and 38417, 23347 and 155 in case of pig cum fish farming and duck cum fish farming systems, respectively.

[1] 1US$ = Rs 36.00

Sharma et al (1985) worked out the economics of carp culture in relation to its integration to pig farming, duck farming and poultry farming as a mean to minimize the cost of production. He reported that the integrated fish cum pig farming from a .4 ha pond requires an investment level of Rs 23000 gives a return of Rs 39000 yielding thereby 68% net return on variable cost. The cost of production was worked out to be Rs 3/kg. The fish cum duck farming requires an investment level of Rs 14490 which provide total return of Rs 21760. The net return on variable cost and cost of production were estimated to be 50% and Rs 4.48/kg respectively. The integration with poultry farming requires investment of Rs 29000 which yields total return of Rs 43000.

The net return on variable cost works out to 50%. The cost of fish production comes to Rs 3.2/kg. At this point it can be highlighted that integrated farming decreases cost of production. But it is doubted that whether the calculation was carried out on a scientific line.

Janardan Rao and Raju (1989) worked out profit in poly carp culture in Kolleru Lake to the extent of Rs 31027/ha where cost of fish production was observed to be Rs 3.77/kg.

Ranadhir (1990, 1993, 1995) worked out the projected economics of carp culture and seed production. He computed net profit in spawn production from .25 ha pond (Rs 35000), in fry rearing from .04 ha pond for raising one crop (Rs 1598), in fingerlings production from .08 ha pond (Rs 1742). Further, he estimated the economics of composite carp culture at various technology levels with 5 tonnes, 10 tonnes and 15 tonnes of production targets. He found that the net profit to be realised from above technology levels from pond of 1 ha size would be Rs 36400, Rs 67000 and Rs 120000 which comes to be 32, 36 and 48.6 percent of the total cost. Using the All India Coordinated Research Project Data, a quadratic production function was also estimated. Sharma (1990) computed the economics of carp culture in integration with duck, pig and poultry farming systems in West Bengal. He advised the integration results in decreasing cost of production.

Suresh et al (1991) worked out economics of composite carp culture in Madurai district of Tamil Nadu. The found unit cost of production and net return per ha varies from Rs 4.46 to 5.61 and Rs 818 to 2863, respectively.

Padmavathi and Anjaneyulu (1991) in a case study computed the costs and returns on three carp culture ponds with different managerial practices. The net income were found to be Rs 26662, Rs 62600 and Rs 188250 per ha per year respectively on above ponds.

Devasia (1991) found net income per ha on small and large ponds (.4 ha and above) were Rs 5500 and Rs 21200 which yields IRR of 38.4% an 50%, respectively.

Gupta et al (1992) computed the economics of fish seed production project for 1 ha farm with eco-hatchery. The approximated that the capital costs, operational costs, gross income and net profit would be Rs 350000, 240000, 297000 and 57000, respectively.

Usha Rani et al (1993) estimated net return per crop per ha from brackishwater prawn farm to be Rs 46148 which is 52.8% to total annual capital investment. Resource use efficiency based on Cobb-Doughlas estimate showed that feed input was over utilised.

Palanisamy and Ghosh (1993) discussed different technological options for aquaculture development. The comparative account of economics of different systems was analysed.

Ghosh and Palanisamy (1993) explained the technology, infrastructural facilities and financial viability of small hatchery of 5 million capacity.

Jayaraman and Varadarajan (1993) used linear programming technique to estimate coefficients of frontier production function on composite carp culture ponds in Thanjavur district. Overall annual yield, gross income, total cost and net income were worked out to be 881 kg, Rs 19661, Rs 7367 and Rs 12594 per ha, respectively. Optimum farm plans of integrated farming systems was worked out. The net income raised in the improved farm plans was Rs 15899 to 15235 is twice to the conventional plan. The optimum farm plan also shows reduction in level of risk.

Shrivastava (1994) estimated linear and log linear production functions using field level input-output data from composite carp culture ponds and found prevalence of decreasing returns to scale. The new return and percentage of net return total cost was worked out to be Rs 13708 and 82 percent, respectively.

Jayaraman, et al (1995) worked out economics of integrated fish-duck-azolla farming system. Returns over cash expenses, return over total cost and net returns of the integrated farming system computed to Rs 19658, Rs 17060 and Rs 17200, respectively. Also, 126 mandays of employment opportunities were generated additionally.

Shrivastava, et al (1996) examined the appropriateness of functional forms in specification of production function. Based on value of R2 and number of significant variables, it was inferred that C-D form is the best fit and superior to linear form in estimation of input-output relationship on KVK adopted composite carp culture ponds. The economic efficiency was estimated as .33 showing thereby scope of improvement in profit to the extent of 67% through managerial improvement and judicious allocation of given resources. The contribution of natural productivity to total fish production was estimated to be 40 to 60%. The increasing returns to scale was observed signifying there by increasing the farm size.

b) Constraints analysis

The constraints analysis focuses mainly issues related to the yield gap and factors responsible for differential adoption of the technology among the farmers and between the regions. Only a very few number of studies were carried out on this aspect and discussed below.

Vasantha kumar and Selvaraj (1988) found mean yield on composite carp culture pond 880 kg/ha as against the demonstration tank yield of 3000 kg/ha and experiment station yield of 8000-10000 kg/ha. The constraints responsible for the wide gaps were resource constraints, production constraints, management constraints and marketing constraints. He opined that, though new technology proved to be superior, the wide gap calls for an effective extension strategy with adequate trained staff for speeding up effective transfer of technology from lab to land.

Shrivastava et al (1990) evaluated fish farmers development agency programme (FFDA) in India considering economic, financial and marketing parameters. The came out with highlighting constraints in success of the programmes and suggested necessary improvement.

Shrivastava (1995) carried out decomposition analysis with experimental data and without experimental data and found yield gap to the extent of 74.9% contributed together by technological efficiency component (-5.2%) and difference in input use (80.1%).

c) Equilibrium in factor and product market-demand and supply analysis

This section pertains to the studies focusing on modeling of equilibrium into factor and product market and also the evaluation of structure, conduct and performance of the carp fish market.

Shrivastava, et al (1994) estimated the engle function for fishing and nonfishing households separately for food items and non food items. In overall income elasticity of expenditure for fishing households was .4 and for non fishing households .3. It is mainly because the fish farmers are belonging to lower income class characterized by a high population in family compare to non fish farmers. This is absolutely according to theory of consumption. Further, it was also noted that elasticity for food items were of lower magnitude (.39 for fishing and .28 for non fishing) compare to non food items (.42 for fishing and .58 for non fishing households).

Nayak (1995) using discriminant function showed that marketing margins and the price paid by the consumers are the two important variables which discriminate significantly the price received by the fishermen at the landing point. Further, it was quantified that the marine catch can be increased to the extent of 2.11% in short run and 1.18 percent in long run in domestic market. Liberalization of world trade was advocated.

Shrivastava and Ranadhir (1995) examines the efficiency of fish marketing in Bhubaneswar City. Three marketing channels were investigated. The channel III showed that 85% of the demand for fish was met by fish producers of Andhra Pradesh. The producers share in consumers rupee was highest for local producers. Largest component of price spread and net margin was attributed to retailers followed by wholesalers and commission agents. There exists a scope of earning super normal profit by intermediaries because market was not perfectly competitive. It is recommended that government should formulate suitable aqua-price policy for eliminating imperfection from the market.

ii) Ongoing research

a) Socio-economic Study of Sustainability of Shrimp Culture in Nellore District of Andhra Pradesh is undertaken by CIBA, Chennai, Tamil Nadu

b) Optimum Planning Model for Fish Farming Systems in India is undertaken by CIFA, Bhubaneswar, Orissa.

The foregoing review of literature reveal that rarely any comprehensive study has been carried out to analyze the impact of aquaculture technologies on socio-economic status of the farmers considering the need for appropriate policy formulation and sustainable aquaculture development. Most of the studies were taken to estimate cost, return and profit of the aquaculture projects. No attempts were made to carry out applied policy oriented research specially on aspect of measurement of technological changes in relation to sustainability in different culture systems and seed production of carps. Also, except few of the studies, the quantification/modeling of different parameters by application of quantitative techniques was found absolutely lacking specially for measurement of technological efficiency, technological bias, elasticity of substitution and returns to scale which spell out the nature of technological advancement. Without these estimations, one can not conclude any thing about the technological advancements whether these changes are superior innovations and could be able to bring a positive breakthrough in an economic systems. Furthermore, neither any study has been taken nor suitable methodologies have been developed to formulate the sustainable technology model. However, no comprehensive studies were taken to measure the efficiency of production systems and constraints thereof. The effect of technological advancement on equilibrium of factor and product market of the carp industry and also the changing scenario of market structure, conduct and performance were not studied.

FUTURE RESEARCH NEED

Some of the research needs for the development of aquaculture in general, and carp farming industry, in particular, may include the following:

1. Measurement of technological change between different culture systems and between different species of carps.

The technological improvements always changes the shape of the production function. This shift causes two major impacts based on which a technology is considered to be socially and economically desirable. The first component is the nature of the change which decides upon the social sustainability of the technology. The second component is the increase in the technological efficiency which in long run affect the economic growth of the country. Moreover, the effect of improvement on productivity and efficiency over a period of time should also be examined. So, studies should deal with two major aspects of the technological change.

i) *Nature of technological change*

a) Neutral vs non neutral technological change
b) Technological bias
c) Elasticity of substitution
d) Returns to scale

ii) *Impact of technological change on*

a) Productivity and technological efficiency between the culture systems - a cross sectional analysis
b) Sustainability (i.e. measurement of productivity growth or loss in productivity over period of time for a culture system)

Social sustainability includes effect on labor absorption/employment, relative and absolute factor shares and factor demand and output supply functions. The changes in employment level may be decomposed into the attributable factors such as technology effect, complementary input effect and effect of prices of inputs and output. The estimation of absolute factor shares will ensure whether the technology is capable of elimination of absolute poverty, whereas the measurement of relative factor shares will reflect the role of technology on income inequality of the region and finally resulting into social tension and unrest.

c) Shift in farming systems and risk considerations

The aquaculture technologies change the farming systems of a particular region. There are two types of changes, one resulting in big aquaculture farms and two, as a dominating component of the agricultural system (mixed farming system). In both of the cases optimum model for the farming systems should be developed considering tradeoff between productivity and risk for different categories of farmers.

2. Constraints analysis

The constraints analysis has two distinct components

i) Yield gap analysis - the yield gap analysis is carried out to examine the extent of shortfall in yield and socio-economic and bio-physical constraints responsible for the gaps between experiment station yield and demonstration farms yield (Yield Gap I) and the gap between yield of demonstration farms and yield at actual farmers field (Yield gap II). It also analyses the magnitude and causes of inter-regional variation in performance as a technology.

ii) Adoption analysis - it includes the socio-economic factors responsible for differentional adoption of technology (like education, credit, technology transfer mechanisms, i.e. state vs private) into different regions and between different class of farmers.

3. Efficiency of the production systems and the constraints thereof

The examination of efficiency of a production systems will guide us to increase the profitability of the business with the same technology and the resource base. Technical efficiency is classified as follows.

- i) technical efficiency
  - purely technical efficiency
  - scale efficiency
  - congestion efficiency
  - system efficiency
- ii) allocative efficiency
- iii) economic efficiency

4. Equilibrium in factor and product market

- i) Estimation of factor demand and factor supply functions
- ii) Estimation of output demand and output supply functions
- iii) Simultaneous equilibrium in factor and product markets

5. Evaluation of market structure, conduct and performance

- i) Marketing channel, marketing margin and marketing costs
- ii) Efficiency of fish marketing
- iii) Market policy, price determinants, and constraints and their possible solutions

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SOCIOECONOMIC ISSUE TO INDONESIAN CARP INDUSTRY

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Indonesia is producing two major species of carps i.e., common carp (*Cyprinus carpio*) and Nilem carp (*Osteochilus hasselti*), and Java barb (*Puntius javanicus*). It is the world's third largest producer of common carp after China and USSR. Common carp comprised about 92% (146,000 mt) of the country's total carp production in 1994 (FAO, 1996). Most or 96% of the common carp production comes from aquaculture (paddy fields, 42%; fish ponds, 38%; and cages, 16%) and only 4% from capture fishery (Table 1).

Table 1: Common carp production in Indonesia, 1993

Sources of production	Production (mt)	Share (%)
Aquaculture		
Ponds	51,773	37.96
Cage	22,498	16.50
Paddy field	56,813	41.66
Capture	5,287	3.88
Total	136,371	100.00

Source: DGF (1996)

Common carp production from aquaculture registered a moderately high annual growth rate of 12 % from 1985-1994. Production from cage culture posted the highest annual growth rate at 82 % mainly due to its low production base. While production from pond and paddy field have annual growth rates of only 10% and 8%, respectively (Table 2).

Table 2: Common carp production by cultured system in Indonesian (mt), 1985-1994

Years	Ponds	Cage	Paddy field	Total
1985	24,209	586	29,933	54,728
1986	29,233	482	38,415	68,130
1987	31,643	1836	54,357	87,836
1988	36,001	3,347	44,674	81,402
1989	34,601	4,584	47,956	87,141
1990	37,636	4,063	47,550	89,249
1991	35,947	5,402	43,020	84,469
1992	40,213	5,646	47,647	50,508
1993	51,773	22,498	56,813	131,084
1994	52,626	28,645	53,967	135,238
Annual growth rate (%)	9.49	81.59	8.21	11.55

Source: DGF (1996).

Though common carp is cultured throughout Indonesia, its bulk of production comes from the province of West Java. In 1994, West Java shared about 70% of the total cultured common carp production of the country (Table 3).

Table 3: Common carp production by culture system and provinces in Indonesia (mt.), 1994

Provinces	Ponds	Cage	Paddy field	Total
Sumatra	15,105	984	10,195	26,284
DI Aceh	1,184	10	2,176	3,370
North Sumatra	4,010	296	4,760	9,066
West Sumatra	4,412	308	1,521	4,841
Riau	222	56	17	295
Jambi	327	147	9	483
South Sumatra	3,157	122	906	4,185
Bengkulu	903	45	655	1,603
Lampung	890	-	151	1,041
Java	33,129	25,764	40,813	99,06
DKI Jakarta	145	-	-	145
West Java	31,119	25,348	37,558	94,025
Central Java	980	318	836	2,134
DI Yogyakarta	242	48	214	504
East Java	643	52	2,205	2,900
Bali- Nusa Tenggara - Timor	449	59	856	1,364
Bali	166	6	291	463
West Nusa Tenggara	207	5	551	763
East Nusa Tenggara	76	-	14	90
East Timor	-	48	-	48
Kalimantan	696	746	26	1,468
West Kalimantan	462	89	1	552
Central Kalimantan	-	-	-	-
South Kalimantan	181	321	25	527
East Kalimantan	53	336	-	389
Sulawesi	3,244	1,092	2,077	6,413
North Sulawesi	1,661	1,076	1,380	4,117
Central Sulawesi	710	16	5	731
South Sulawesi	560	-	692	1,252
South East Sulawesi	313	-	-	313
Maluku-Irian Jaya	3	-	-	3
Maluku	3	-	-	
Irian Jaya	-	-	-	
Total	52,626	28,645	53,967	135,238

Source: DGF (1996).

CARP CULTURE SYSTEM

Carp farmers are either or in combination engaged in hatchery and grow-out operation following a monoculture or polyculture systems,. On the average, fry production per kg breeder of hatchery farms in the country is ranging from 50,000 to 80,000 (Gustiano et al., 1992). For grow-out operators, they are raising carps in a rice-fish farming, floating netcage and running-water system (Gustiano, 1994).

The rice-fish carp culture system is undertaken in cultivated rice field with the sequence: rice-fish (*mina-padi*), fingerlings/postfingerlings (*penyelang*), and *palawija ikan* or secondary fish crop. The last two culture systems are more widely practiced than the first (Cruze, 1990). The two main types of rice-fish farming are the concurrent and rotational culture. In the concurrent culture (*mina-padi*), fish are cultured with the rice crop for 1-2 months. In the rotational culture, fish are cultured between two rice croppings for about one month or when rice fields is being prepared for the next cropping; or as a single crop for 2-3 month after the second rice crop or during the fallow period after the first rice crop. Expansion of rice-fish culture is very promising as it provides the food, income and employment to rural population as well as it supplies fry/fingerling requirements of the carp industry.

Floating net cages for carp culture were first introduced as one of the activities under a resettlement program for families from the inundated areas (Gustiano, 1994). Since then, there was a rapid increase the number of floating net cage. In February 1989, in the Saguling, Cirata, and Jangari reservoirs in West Java and Wonogiri reservoir in Central Java, there were 1,200, 60 and 45 units of floating net cages in operation, respectively. In June 1990, floating net cages in operation increased to over 400 units in the Cirata reservoir and about 190 units at Jangari. Good road networks, access to fish market, feeds and fry supply are the main factors that have accelerated the development of cage culture in these areas. Carp cage culture in reservoirs has now considerable impact on fish production in Indonesia. Annual fish production from cages, which have been steadily increasing in numbers, is currently estimated to be over 600 mt. For each unit of cage of approximately 7 x 7 x 2 m, it is possible to produce 1200 to 1500 kg of fish per harvest.

Running water system has been adopted by farmers since 1975 (Gustiano, 1994). The culture of fish in running water system has been practiced in areas where water is abundant throughout the year. The two common methods of fish culture under running water system are: 1) installation of fish cages in stream and river; and 2) construction of ponds with different elevation, in which water diverted from stream or river is supplied to ponds by gravity.

The duration of culturing carp in running water ponds is about 2 to 4 months depending on the initial weight of fish stocked and marketable size preferred by the buyers. Most farmers are harvesting the fish by completely draining the ponds. Usually 3 crops of fish are produced each year with a net production ranging from 40 to 90 kg/m^2 (Lim, 1986). The size of fish at harvest is usually from 250 to 600 g. The survival rate is about 95 to 99 %. At the present, the most popular fish being cultured in this system and highly preferred by consumer, especially for Sundanese ethnic in West Java, is common carp.

Carp culture in ponds is very popular in Indonesia. About 74.7 % of fish farmers are culturing carps in fishponds and only 23.7 % are raising carps in paddy field and 1.6 % in cages. Fish farmers are operating a net water surface area of ponds, cages and paddy field ranging from 0.02 ha to 0.26 ha, 0.75 m^2-158.30 m^2 and 0.20 ha-0.56 ha, respectively. The details of the distribution of fish farmers culturing carps by geographical location and their farm sizes are shown in Table 4.

Table 4: The number of fish farmer household and average size of carp farm, Indonesia, 1994

Provinces	Ponds		Cage		Paddy Filed	
	Farmers	Area (ha)	Farmers	Area (m2)	Farmers	Area (ha)
Sumatra	246,877	0.08	11,881	3.90	45,917	0.56
Java	1,037,379	0.02	4,255	10.03	340,036	0.29
Bali-N.Tenggara-Timor	40,316	0.06	41	8.78	28,552	0.20
Kalimantan	32,514	0.05	12,123	1,52	376	0.55
Sulawesi	20,691	0.26	1,185	0.75	25,267	0.37
Maluku-Irian Jaya	11,002	0.02	247	158.30	-	-
Total	1,388,779	0.04	29,731	4,97	440,147	0.31
%age (%)	74.72		1.60		23.68	
1984-1994, Annual growth rate (%)	6.63		9.38		6.89	

Source: DGF (1985).

INCOME OF CARP FARMERS' HOUSEHOLD

Carp culture is just one of the main sources of income of the household of carp farmers. Agriculture, trading and employment (government sector) are their other major sources of income. Of the total income of carp farmers' household of Rp 4,206,136 in Saguling reservoir in 1994, income from fishery which include carp farming, agriculture, trading and employment comprised about 39, 15, 17 and 30 %, respectively (Table 5).

Table 5: Distribution of fish farmer household income in Saguling reservoir, 1994

Income Sources	Income (Rp)	% age (%)
Fishery	1,631,502	38,79
Agriculture	619,636	14,73
Trading	710,000	16,89
Government official	1,245,000	29,59
Total	4,206,138	100,00

Source: Azizi, et al, 1993/1994.

INPUT USE AND PROFITABILITY OF CARP FARMING

Intensive carp culture in continuous flow (running water) ponds and floating net cages is characterized by the used of higher rates of material inputs and capital. In semi-intensive carp cage culture, feeds come mainly from the organic materials carried downstream. Supplementary feeding with kitchen wastes, agricultural by-products and fresh leaves are supplied occasionally. While carp farming in rice fields and standing water (ponds) depend mainly on natural food as a source of nutrients.

The typical costs and returns of intensive carp cage culture is shown in Table 6. Fry and feed costs constituted about 92-93 % of the total production cost. Total production cost in Cirata (Rp 31.97 million) was higher than in Saguling (Rp 20.53 million). This indicates that carp cage culture in Cirata was more intensive that in Saguling. Despite the higher production cost, net return of carp cage culture in Cirata (Rp 5.47 million) was higher than in Saguling (Rp 3.35 million), an indication that using higher levels of inputs result to higher production. Nevertheless, there was no difference in the B-C ratios of carp cage culture in Cirata and Saguling (1.16 vs. 1.17). This shows that in both locations, carp farmers attained the same degree of financial efficiency.

Table 6: Cost structure, total cost, gross and net return of floating net cage in Cirata and Saguling reservoirs in Indonesia, 1990

Items	Cirata[1]	Saguling[2]
Fixed cost (%)	3.2	1.8
Fingerling (%)	46.7	43.5
Feed (%)	46.7	48.8
Labor (%)	1.3	5.8
Others (%)	1.1	-
Total cost (%)	100.0	100.0
Total Cost (Rp)	31,968,000	20,525,456
Gross Return (Rp)	37,440,000	23,874,048
Net Return (Rp)	5,472,000	3,348,592
Benefit-Cost ratio	1.17	1,16

Note: Size of cage: 7 x 7 x 2.5 m (4 units); number of croppings: 4 times in a year
Sources: [1]Sadili (1990) and [2]Sadili, *et al.* (1990).

Other studies on profitability of carp culture in cages and paddy fields are shown in Table 7.

Table 7: Profitability of carp farming in Indonesia (various sources)

Sources	Total Cost (Rp)	Gross Return (Rp)	Net Return	Notes
A. Cage				
Sadili and Koeshenra-jana (1989)	4,422,527	5,517,143	1,094,620	Surveyed 30 fish farmers in Saguling, West Java, one period production with 4 units of cage
Sadili, *et al.* (1991)	1,282,841	1,492,128	209,287	Surveyed 40 fish farmers in Saguling reservoir, West Java, one period of production in 2,6 month with one unit of cage
Nikijuluw, *et al.* (1992)	2,163,535	2,420,000	256,465	Surveyed one unit of cage in Cirata and Saguling reservoirs in one harvesting period
B. Rice Field				
Koeshenraja na and Sadili (1989)				
Mina padi	536,934	885,700	349,306	Survey 30 fish farmers in Subang District,
Penyelang	108,005	159,992	51,987	West Java, one ha basis
Palawija ikan	241,794	496,020	254,227	

CONSTRAINTS IN CARP FARMING

At the national level, fish farmers' lack of skills to implement the required cultural practices. Under utilization of the rich water resources is another major problem constraining the development of freshwater aquaculture in Indonesia. Utilization rate of water bodies is only about 30 %, and only 3 % is intensively utilized for fish farming (Djajadiredja. Et al., 1981 in Sadili, 1989).

At the farm level, lack of operating capital, high cost of feed, low price of fish and poor fish quality are the major problems faced by (grow-out) carp farmers (Lim, *et al*, 1986). While, most of carp hatchery operators are having problem of high fish mortalities in ponds during the first 21-30 days (Nursery I cycle) after egg hatching (Barry, et al., 1990).

"Small" fish farmers considered lack of capital to purchase seeds, feed and other operational expenses as their major problems. Some farms, though with a total area of less than 200 m^2, were not fully operational due to the lack of capital. In addition, most small farmers are obliged to purchase feed through credit from the middlemen at high interest rate. Local middlemen are usually big farmers who are also feed dealers and fish brokers (Lim, *et al*, 1986).

Fish production of carp farmers operating fishponds, especially those with high degree of dependence from irrigation water are adversely affected by the frequent fluctuation in the volume and quality of water during the year. In some farms, parasites and diseases problems have been encountered. However, these have not yet been considered as serious problems among fish farmers (Lim, et al., 1986).

From 1976-1986, the culture of common carp in running water was a good business due to higher prices. But onwards, with the introduction of carp culture in floating net cages, there have been drastic reduction in the prices of carps in due to production glut. Even West Java, which has a good market price for common carp, is affected during periods of bumper production.

Prices of inputs have been increasing substantially in Indonesia. For fry/fingerling, it is not only its increasing price but also the lack of good quality and the instability of its supply that are causing economic losses to carp farmers. Often fry are not available at the right time delaying the production cycle of fish farmers. The increased in the prices of fry/fingerlings can be attributed to high demand from fish culture floating net cage in man-made lakes or reservoirs. The price of feed is also increasing from year to year. While, the increase in the price of fish usually is not proportional with the increase in input prices. There is also the attitude that when a farmer in particular location was successful, others would follow. These new farmers would usually construct their farms further upstream from the old farm. Consequently, polluting the ponds in downstream which result in slow growth and high feed conversion rates (Hardjamulia and Suhenda, 1991). Other problem is water use conflict between the running water pond and floating net cage systems.

DEMAND FOR CARPS

The demand of carp is determined mainly by its market price. The price of carp depends on the fry price, fry supply, fish size, transportation, ethnic preference, and season. Gustiano (1984) reported that in July 1992 at Cisaat fish market showed that the market price of carp was Rp 2500-3000/kg (US$1= Rp 2200). Normally, the price of carp is fluctuating around Rp 2000/kg that reach its peak in October and bottom in March. As carp is most preferred fish by Sundanese ethnic, its production is concentrated in West Java, the province occupied by this ethnic group.

Fish consumption is on the uptrend. From a per capita fish consumption of 9.96 kg/year in 1968, this increased to 15.91 kg/year in 1993 at an annual growth rate of 1.9 %. The increasing demand for fish can be attributed to the general improvement of the country's economy. As their income increases, prices of fish is becoming affordable to most people and their fish consumption also increases. This can be expected as the income elasticity of fish demand of 1.06 can be considered elastic, which means that an increase in income will induce more demand for fish proportionately.

In addition, fish demand or consumption of fish and carp in particular can be expected due to consumers' high preference for fish as their main source of animal protein as they are becoming more health conscious. They are aware that fish has high protein content and has low level of cholerol that reduces their risk of heart attack (CBS, 1995).

EXISTING RESEARCH ON SOCIOECONOMICS OF CARP CULTURE

In Indonesia, most of the socio-economic research on carps dealt on the benefit-cost analysis of the production and marketing of grow-out and hatchery operators under different carp culture system.

So far, the following are the socio-economic studies on carp under different culture systems: 1) running water (Cruz ,1992; Lim, Suhenda, and Djajasekawa, 1986; Gustiano, 1994); 2) floating net cage (Sadili and Koeshendrajana, 1989; Sadili, 1990; Sadili, et al., 1991; Nikijuluw, Sadili, and Ismail; 1992; Azizi, et al., 1994); and 3) rice-fish culture (Gustiano, 1994; Barry, et al., 1990; Koesemadinata and Barry, 1985; Yunus, et al., 1988; Sastradiwirja, 1988; Fagi, Suriapermana, and Syamsiah, 1988; Dela Cruz, 1991).

Research activities in Indonesia are mostly carried out by government institutions. Carp fish research is specially conducted by Research Institutes for Freshwater Fisheries in Bogor and Sukamandi and the Fresh Aquaculture Development Centre, Sukabumi. These institutes are under the Agency for Agricultural Research and Development, Department of Agriculture. Other institutes doing research in fishery are Department of Fishery, some government universities, such as Universities of Riau, Bogor Agriculture, Brawijaya, Hasanuddin, Pattimura, Sam Ratulangi, and private universities.

FUTURE RESEARCH NEED

As discussed earlier, the following are the identified major problems of fish farmers: lack of reliable of sources of quality fry/fingerling, increasing prices of inputs especially of feeds and fry/fingerlings, controlling/preventing predators, pests and diseases, lack of operating capital, and low prices of carps during production glut and the seasonality of fish production.

Hence, the following research needs have to be carried if we are to support and sustain the development of the carp farming industry in Indonesia:

1. Productivity, benefit-cost analysis, and level of technology used in carp fish culture in terms of species, size of farm, culture system, and area.

2. Estimation of demand function of carp and consumer behavior in terms of species, group of people, location and season.

3. Identification of potential market (domestic and international)

4. Improvement of the function of any related institutions to strengthen fish farmers bargaining position, accessibility to capital or financial sources, adapted technology, market, and information.

5. Substitution of expensive feed ingredients with locally available cheap materials to reduce the feed cost. Also, determination of optimum feeding rate, including frequency and method, and stocking densities in relation to the quantity and quality of water for maximum utilization of water resources for carp culture.

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SOCIOECONOMIC ISSUES RELATED TO CARP INDUSTRY IN THAILAND

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In Thailand, freshwater fish species are important source of animal protein and highly affordable to consumers. Tilapia, carp and catfish are the major freshwater species of economic importance to the fishery sector of the country.

Carp is one of the popularly farmed species in Thailand. It is contributing about 18 and 14 % to total quantity and value of freshwater fishery production of the country (Table 1).

Table 1: Production of freshwater fishery in Thailand, 1994

Species	Quantity (t)	%	Value (million Baht)	%
Nile tilapia	55,720	33	1,003	21
Walking catfish (Pla-Duk)	34,660	20	828	17
Thai silver barb	27,210	16	594	12
Common carp	2,820	2	73	2
Others	50,020	29	2,334	48
Total	170,430	100	4,834	100

Source: Fishery Economics Division, Department of Fisheries (DOF), Thailand

Carp production comes from aquaculture and capture fisheries. Based on a five-year average (1990-1994), capture fishery accounted for the bulk or 57 % of carp production. Production from aquaculture amounted to only 43% of the total carp production. Nevertheless, carp production from aquaculture showed a robust growth rate than the capture fishery. In fact, the 1994 carp production level from capture fishery was already 3 % lower than its 1993 level (Table 2). With robust growth rate and strong government support for the development of freshwater aquaculture, it is expected that carp production from aquaculture will continue to post substantial growth in the near future and will eventually be the major source of carp production in the country.

The Thai silver barb and common carp are the two major species cultured and caught in the inland freshwaters of Thailand. The Thai silver barb is dominating both the carp production from aquaculture and inland capture fishery. This is expected as the Thai silver barb has long culture history, being a native carp species than common carp, an exotic species.

Table 2: Carp production (t) in Thailand, 1990-94

Year	All carp species[1]			Thai Silver barb			Common carp		
	Culture	Capture	Total	Culture	Capture	Total	Culture	Capture	Total
1990	16,700	29,700	46,400	14,600	26,000	40,600	2,100	3,700	5,800
1991	18,800	29,900	48,700	16,300	23,100	39,400	2,500	6,800	9,300
1992	26,100	29,100	55,200	23,800	22,400	46,200	2,300	6,700	9,000
1993	25,000	31,800	56,800	21,900	23,100	45,000	3,100	8,700	11,800
1994	30,000	30,700	60,700	27,200	22,500	49,700	2,800	8,200	11,000
% Share (1990-94)	43	57	100	47	53	100	27	73	100

[1] Refers only to major species of carp i.e., Thai silver barb and common carp
Source: Fishery Economics Division, Department of Fisheries (DOF)

Table 3 shows the geographical distribution of carp aquaculture production by species and culture system. Though carp is cultured in six regions, its production is concentrated in Northern Thailand. About 35 % of its aquaculture production is coming from this region. Carps are cultured in ponds, paddy fields, ditches and cages. Most or 92% of carp production from aquaculture is coming from fishponds. Due to its recent introduction, carp production from cages is negligible. Carp cage culture is only found in Northern and Northeastern and Central-Plain regions.

Table 3: Carp production (t) by species and culture system in Thailand, 1994

Species/culture system	Total	Northern	North-Eastern	Central-Plain	Eastern	Western	Southern
All species[1]	30,029	10,475	6,702	4,794	3,842	3,474	740
Pond	27,578	10,309	5,796	4,718	3,634	2,429	690
Paddy field	2,035	114	904	38	208	774	
Ditch	414	52	a	38		271	50
Cage	2	a	2	a			
Thai silver barb	27,211	9,709	4,980	4,763	3,599	3,470	689
Pond	25,095	9,577	4,372	4,690	3,391	2,425	639
Paddy field	1,713	90	606	35	208	774	
Ditch	401	42	a	38		271	50
Cage	2	a	2				
Common carp	2,818	766	1,722	31	243	4	51
Pond	2,483	732	1,424	28	243	4	51
Paddy field	322	24	298	3			
Ditch	13	10					
Cage	a			a			

a = less than 1 ton.
[1] Refers only to major species of carp i.e., Thai silver barb and common carp.
Source: Fishery Economics Division, Department of Fisheries (DOF)

Table 4 shows the distribution and area of carp farms by region, species and culture system. Though bulk of carp production is coming from Northern Thailand as shown in Table 3, high concentration of carp farms and areas for carp farming is found in Northeastern Thailand. About 57 % and 60 % of the total number of farms (67,012 farms) and total area (101,111 rai) for carp farming are concentrated in this region. This indicates that there are differences in regional productivity of carp farming in Thailand.

Raising carps in fishponds are widespread than farming them in paddy fields, ditches and cages. Fishponds constituted about 91 % of the total numbers of carp farms. Again, most of the fishponds are concentrated in Northeastern Thailand (Table 4).

Table 4: Geographic distribution and area of carp farms by fish species and culture systems in Thailand, 1994

Species/culture system	Total	Northern	North-Eastern	Central-Plain	Eastern	Western	Southern
1. All species [1]							
A. No. farms	67,012	16,213	38,017	5,166	1,033	2,083	4,500
Pond	60,890	15,904	33,019	4,771	932	1,822	4,442
Paddy field	5,300	160	4,941	103	61	30	5
Ditch	798	148	37	289	40	231	53
Cage	24	1	20	3			
B. Area (rai [2])	101,111	17,256	60,217	10,989	3,163	6,542	1,939
Pond	71,897	15,236	38,515	8,858	2,062	5,358	1,864
Paddy field	26,142	1,791	21,628	1,403	990	313	18
Ditch	2,067	230	69	728	111	871	57
Cage	6	a	5	a			
2. Thai silver barb							
A. No. farms	56,038	13,913	29,745	5,129	1,014	2,039	4,198
Pond	51,572	13,703	26,280	4,749	914	1,783	4,143
Paddy field	3,700	92	3,413	102	60	29	4
Ditch	744	117	32	277	40	227	51
Cage	22	1	20	1			
B. Area (rai [2])	83,382	14,589	45,406	10,943	3,140	6,485	1,814
Pond	61,166	13,237	30,001	8,834	2,043	5,306	1,741
Paddy field	19,193	1,137	15,346	1,400	986	309	16
Ditch	2018	216	54	709	111	870	57
Cage	6	a	5	a			
3. Common carp							
A. No. farms	10,974	2,300	8,272	37	19	44	302
Pond	9,318	2,201	6,739	22	18	39	299
Paddy field	1,600	68	1,528	1	1	1	1
Ditch	54	31	5	12		4	2
Cage	2			2			
B. Area (rai [2])	17,729	2,667	14,811	46	23	57	125
Pond	10,731	1,999	8,514	24	19	52	123
Paddy field	6,949	654	6,282	3	4	4	2
Ditch	49	14	15	19		1	a
Cage	a			a			

a = less than 1 rai.

[1] Refers only to major species of carp i.e., Thai silver barb and common carp.

[2] 1 rai= 0.16 ha

Source: Fishery Economics Division, Department of Fisheries (DOF), Thailand

PROFITABILITY OF CARP FARMING

The cost of Thai silver barb production per farm and per hectare is shown in Table 5. Carp farmers incurred a total production cost of Baht 21,022/farm or Baht 8,984/ha. Cash and non-cash costs constituted about 73% and 27% of the total production cost, respectively. Feed alone accounted for about 35% of the total production cost, an indication that carp farming is a commercialized aquaculture activity.

Table 5: Costs of carp production (Thai silver barb) in Thailand, 1995

Item	Production cost (Baht)		%
	Per farm	Per hectare	Cost
Cash costs:	15,438	6597	73
Fingerling	4,057	1734	19
Feed	6,446	2755	31
Labor	948	405	5
Antibiotic/chemical	195	83	a
Fuel/electricity	1,406	601	7
Small tools	79	34	a
Maintenance	288	123	1
Interest/opportunity cost	1,530	654	7
Land rental/tax	343	147	2
Others	146	62	a
Non-cash costs:	5,584	2386	27
Fingerling	265	113	1
Feed	822	351	4
Labor	1,731	740	8
Antibiotic/chemical	4	2	a
Interest/opportunity cost	229	98	1
Land rental/tax	1,374	587	7
Depreciation	1,158	495	6
Others	1	b	a
Total cost	**21,022**	**8984**	**100**

a = less than 1 percent; b = less than 1 Baht
[1]Major species being cultured and harvested as carp farmers are practicing polyculture system.
Source: Office of Agriculture Economics, Mininistry of Agriculture and Cooperative, Thailand

Table 6 shows the cost and return of carp farming (Thai silver barb). With an average production of 2,398 kg/farm or 1,025 kg/ha, carp farmers are earning a gross income of Baht 36,354/farm or Baht 6,552/ha and a net income of Baht 15,332/farm or Baht 6,552/ha. They incurred only Baht 8.77 to produce 1 kg of carp. With a farmgate price (Baht 15.16/kg) almost twice the cost to produce a kilogram of fish, carp farming can be considered a highly profitable aquaculture activity.

Table 6. Cost and return of carp production (Thai silver barb[1]) in Thailand, 1995

Item	Per farm	Per hectare
Average production (Baht)	2,398	1025
Farm price (Baht/kg)	15.16	15.16
Gross return (Baht)	36,354	15536
Total variable cost (Baht)	18,147	7755
Total cost (Baht)	21,022	8984
Return over variable cost (Baht)	18,207	7781
Net farm income (Baht)	15,332	6552
Cost of fish/kg (Baht/kg)	8.77	8.77

[1]Major species being cultured and harvested as carp farmers are practicing polyculture system.
Source: Office of Agriculture Economics, Mininistry of Agriculture and Cooperative, Thailand

CONSTRAINTS TO HIGHER CARP YIELD

Three major factors are identified constraining the attainment of higher carp yield in Thailand:

1. Natural and environmental constraints
   Flood, reduced rainfall (drought), water pollution are some of the major natural and environmental problems affecting carp yield in Thailand.

2. Biological and technical constraints
   Small-size fish at harvest, disease outbreak, lack of technical assistance are some of the biological and technical factors constraining higher carp yield in the country.

3. Socioeconomic constraints
   Net/pond destruction/vandalism, poaching, lack of operating capital, increasing cost of inputs and high fluctuation in output prices are some of the socioeconomic problems affecting carp farming productivity in Thailand.

PRICES OF CARP SPECIES

Farm prices of carps are ranging from Baht 19-27/kg (Table 7). As consumers have high preference for common carp, it is usually priced higher than Thai silver barb. There have been considerable fluctuation in the monthly farm prices of Thai silver barb and common carp. Farm price of Thai silver barb is at its lowest level usually in October and at its highest in December. While, common carp farm price is at its lowest level in November-December and at its highest in April. The lowest and highest levels of farm prices of Thai silver barb and common carp are directly associated with their peak and lean production months. As their production peak, their farm prices are at its lowest level and vice-versa.

Table 7: Two-year carp monthly average farm prices in Thailand, 1993-1994

Month	Thai silver barb		Common carp	
	Price (Baht/kg)	Index	Price (Baht/kg)	Index
January	21.30	100	20.90	100
February	21.14	99	25.62	123
March	21.17	99	25.31	121
April	20.33	95	26.66	128
May	20.17	95	25.36	121
June	21.25	100	24.06	115
July	21.50	101	25.00	120
August	22.50	106	22.50	108
September	20.50	96	20.31	97
October	18.67	88	20.62	99
November	21.75	102	20.00	96
December	22.25	104	20.00	96
Average	22.80		24.95	

Source: Basic data from Department of Business Economics, Thailand

MARKET PRICES AND MARGINS

The monthly prices of Thai silver barb and the price margins obtained by fish traders are shown in Table 8. With an average market price of Baht 25.85 and farmgate price of Baht 22.80, fish traders are earning an average of Baht 3.05 for every kg of Thai silver barb they are trading in the market. At this price margin, fish trading can be considered a lucrative business in Thailand.

Table 8: Market prices and margins (Baht/kg) of Thai silver barb, 1993-1994

Month	Market price[1] (Baht/kg)	Farm price[1] (Baht/kg)	Price margin
January	25.75	21.30	4.45
February	25.00	21.14	3.86
March	25.00	21.17	3.83
April	26.50	20.33	6.17
May	25.00	20.17	4.67
June	25.00	21.25	3.75
July	25.00	21.50	3.50
August	25.00	22.50	2.50
September	25.00	20.50	4.50
October	27.50	18.67	8.83
November	27.50	21.75	5.75
December	27.95	22.25	5.70
Average	25.85	22.80	3.05

[1]Two-year monthly average of prices of Thai silver barb (1993-94).
Source: Basic data from Department of Business Economics, Thailand

FISH DEMAND

Price and income elasticities are usually the major determinants of fish demand. Price (income) elasticity of demand is estimated as the percentage change in quantity demanded associated with a one percent change in price (income), while other factors remained unchanged. When the absolute value of price (income) elasticity is greater than one, the demand for the species is said to be elastic. While the demand for a species is said to be inelastic when the absolute value of price (income) elasticity is less than one.

Table 9 shows the price and income elasticities of demand for major fishery products. Only the absolute value of the price elasticity of Indo-pacific mackerel (1.14) is greater than one. The price elasticities of other species such as crab (0.88), shrimp (0.44) and squid (0.48) are less than one. Thus, except for Indo-pacific mackerel, the demand of major fishery products can only be increased with substantial reduction in prices. However, as income elasticities of these fishery products are greater than one, an increase in income will induce more demand or consumption of these products. Hence, it is expected that there will be a substantial increase in the demand for fishery products including freshwater species as income of consumers are increasing in Thailand.

Table 9: Price and income elasticity of demand for major fishery products in Thailand

Fishery products	Price elasticity	Income elasticity
Indo-Pacific mackerel	-1.14	1.12
Crab	-0.88	3.68
Shrimp	-0.44	1.37
Squid	-0.48	3.83

Source: Jatanavanich (1981).

FUTURE DEMAND OF FRESHWATER SPECIES

The Office of Agriculture Economics has estimated that the demand of freshwater fish species will increase from 224,437 tons in 1992 to 290,492 tons in 2001, or will expand at the rate of 2.919 tons/year. This increase is expected to come mainly from aquaculture as freshwater production from capture fisheries has been declining in recent years. As one of the major freshwater aquaculture species, carp production is expected to increase parallel to increase in demand of freshwater species in Thailand.

EXISTING SOCIOECONOMIC RESEARCH ON CARP CULTURE

No specific socioeconomic research on carp culture has been undertaken yet in Thailand. But, the Office of Agriculture Economics has conducted several research studies on the production and marketing of freshwater species in Thailand. Specifically, these studies are focused on:

1. Production and marketing constraints of freshwater fish species;
2. Socioeconomic of freshwater aquaculture;
3. Costs and returns of freshwater aquaculture; and
4. Production and resource-use efficiency of freshwater aquaculture

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SOCIOECONOMIC ISSUES RELATED TO CARP INDUSTRY IN VIETNAM

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As a rice-fish society, the Vietnamese have a proverb: "Rice and fish like mother and child". Fish are consumed by most people, a very important animal protein source and food security for about 90% of the population in rural areas. Fish consumption is about 15 kg/caput/yr sharing nearly 35% to total animal protein intake (Ministry of Fisheries 1996).

The country's aquaculture sector is one of its major sources of fish products. Aquaculture production amounted to about 0.40 million tons or 29% of the total fish production of 1.37 million tons in 1996 (Table 1).

Table 1: Fish production of Vietnam, 1986-1996 (in '000 tons)

Fishery sector	86	87	88	89	90	91	92	93	94	95	96
Capture	571	612	631	627	641	699	697	748	832	928	970
Aquaculture	235	242	233	247	301	341	356	368	397	419	400
Total production	605	852	864	873	942	1004	1052	1116	1229	1346	1370

Source : Ministry of Fisheries, 1996

Geographically, most or 42 % of the marine fish production comes from South-east Vietnam. While, South-west, Central and Guff of Tokin accounts for only 26, 20 and 12 % of the marine fish production, respectively. In aquaculture production, the Mekong River Delta is playing an important role. It accounts for about 67 % of total aquaculture production of the country (Table 2)

Table 2: Geographic distribution of fishery production in Vietnam, 1996

Fishery sector	Regions	% Share
Marine (capture)	Guff of Tokin	12
	Central Vietnam	20
	South-east Vietnam	42
	South-west Vietnam	26
Aquaculture	North high & mid-land region	6
	Red River Delta	13
	North Central Coast	6
	South Central Coast	2
	Central high-land	1
	South-east Asia	5
	Mekong River Delta	67

SOCIOECONOMICS OF CARP CULTURE IN VIETNAM

Traditional carp culture has long been practiced as early as hundred years ago mainly by the rice farmers. They cultured fish in ricefields and village ponds to supplement their food requirement. The main fish species they cultured are common carp and other indigenous fish.

With the introduction of Chinese carp (silver carp, big head carp, grass carp) and the successful propagation of these species through induced breeding in the 1960's, fresh water fish culture evolved to a new period of aquaculture development in the country. Since then, seed production was no longer dependent on nature. But, carp farming became only an important component of the rural economy in the early 1980s, with the introduction of a major group of Indian carps such as rohu (*Labeo rohita*), mrigal (*Cirrinus mrigala*) and catla (*Catla catla*). As rohu and mrigal are easy to breed and fast growing, they quickly became of economic importance to most fish farmers.

Carps are mainly cultured in polyculture system. The main species cultured are: 1) Chinese carps (silver carp, grass carp and big head carp); 2) Indian carps (rohu, mrigal); and 3) local fish species (catfish, common carp). The culture system is primarily semi-intensive culture using only a minimum amount of fertilizers, rice bran and other agricultural on-farm/off-farm by- products. In addition to polyculture system, an integrated farming system known as a VAC system is practiced popularly in Red River Delta. In the system, V stands for garden, A stands for fish pond and C stands for livestock. This system promotes by-products recycling within the farm and has been accepted by the farmers. In VAC system, fish pond shares the main part of output and income of the farmers.

On the average, farm sizes for carp farming is ranging from 0.5 to 1 ha. The size of pond varies from 200 to 1500 m^2. Normally, each household owned 1 or 2 ponds with water availability throughout the year. Pond water depth ranges from 1.0 m to 1.6 m, considered suitable for carp culture.

Carp culture period often starts at the beginning of rainy season (May-June) and ends in the dry season (December - January). Ponds are often completely drained to facilitate the harvesting of fish. After harvesting, the pond bottom is dried for a few days and is limed, manured and filled with water in preparation for next grow-out season. Water are sourced either from irrigation canal, rainfall or reservoir. After filling the pond with water, fingerlings are stocked.

Carp farmers' household income come primarily from aquaculture, livestock, crop cultivation and other on-farm and off-farm activities. It is estimated that carp farmers have income 2 to 3 times higher than the average rice farmers. Fish farmers are earning an average gross income of about Dong 10 million per ha of fishpond.

The main inputs in carp farming are labour cost, fingerlings, fertilizers and feeds. Members of the household are supplying most of labour requirement in carp farming. There is abundant supply of labour as one household is composed of 5 to 6 persons. Slowly, women are being involved in carp farming. Female members of the household can even provide the necessary labor in carp farming if required.

As in any other aquaculture activities, the cost of carp production consists of costs of fingerlings, feeds, fertilizers, pond management, harvesting cost and other expenses. Overall, the cost of fingerlings has the largest share in total production cost. The rest are costs of manure, rice bran used in aquaculture.

Stocking size of fingerlings varies for different species. Normally, the length of fish being stocked ranges from 8 to 10 cm. The stocking density largely differs from farm to farm depending on the culture system, levels of input use and size of fingerlings available.

Both inorganic and organic fertilizers (including manure, nightsoil) are used in carp farming. In addition, rice bran, aquatic macrophyte and vegetable are commonly used as feeds for carp production in fishpond. Most farmers are sourcing their inputs from on-farm by-products. In some progressive farms, commercial feeds and inorganic fertilizers are also used for carp farming.

On average, about VND 20 million investment are needed to set up a hectare of fishpond in Vietnam. But, this may still be substantially reduced if simple structures are opted upon.

CONSTRAINTS TO HIGHER YIELD IN CARP CULTURE

The main problems faced by fish farmers are inadequate credit, flooding, fish disease, poor extension services, poor quality seeds, poor water quality and too high seed prices. Recently, a government bank catering for the financial needs of the agriculture sector has started providing loans to farmers with low interest rates. However, due to complicated borrowing procedure and the requirement of collateral, most of the poor farmers could not still avail of this cheap credit.

The difficulty to control the damage caused by fish diseases has been the source of heavy economic loss in fish culture. An example is red spot disease, which often occur in carps in cage culture, can completely wipe out the farmers' production. In addition, the lack of good quality fingerlings is also a major constraint to the farmers. Currently, fish farmers have continued buying poor quality seeds even with higher prices from the seed trader so as not to interrupt their production cycle.

Moreover, due to a competition in the use of feeds (including fish meal, rice bran, soybean and other local ingredients) between carp culture with livestock, there is acute shortage of feeds for fish culture all over the country. The use of pesticides in agricultural crop that directly pollutes carp culture has been the major source of high fish mortality in ricefields and village ponds. Poor aquaculture extension services is also a factor constraining aquaculture development in Vietnam.

FISH MARKETING

Fresh water fish culture is mainly practiced by small-scale households in rural areas. Despite the recent entry by some commercial farms using higher levels of inputs to achieve higher productivity, the major part of freshwater fish production is still coming from small-scale farms. As there is limited production, freshwater fish trade is also dominated by small-scale traders. There are two kinds of fish traders: 1) producers/traders, selling directly their produce in the local markets; and 2) "real" traders, dealing mainly with buying and selling of fish products.

"Real" fish traders are buying and selling all kinds of freshwater fish. They are mainly trading common carp, silver carp, grass carp, rohu, mrigal, silver barb, catfish and tilapia. Traders are mainly buying their fish from fish producers and only a small percentage from fellow traders or wholesalers. Obviously, they understand that by dealing directly with the fish producers, they can earn more.

Normally, the fish are sold in local market or near the fish production area. The distance of the market and the source is ranging from 5 to 15 km. Majority of fish traders are transporting the fish from their sources to the market using bicycle and motorcycle. It usually takes them about 20-60 minutes to transport fish from farm sites to market. For that reason, the marketing cost is low and the consumer can buy very fresh fish at a cheaper price. Usually, fish producers by taking directly their produce to the market, get good price and earn more income. As expected, the fish traders sell more fish in the peak season than in the lean season. With negligible difference in the selling prices of fish between peak and lean season, they are earning more income during the peak season due to larger trade volume.

The sizes of fish being traded in the market are ranging from 2-6 fish/kg. Currently, most consumers especially in rural areas show preference for smaller fish. The price of fish varies with fish species, distance from source of fish and market, and regions. Prices of fish in high land regions are usually higher than in other regions (Table 3).

Table 3: Price of carp species in different regions in Vietnam

Fish species	Market price by regions (VND'000/kg)		
	High-land region	Urban region	Rural region
Common carp	18-20	18-20	12-15
Silver carp/big head carp	8-10	5-7	6-8
Rohu/mrigal/grass carp	12-15	10-12	8-10
Silver barb		10-12	8-10

DEMAND FOR CARP

On average, a household consumes about 60-80 kg fish per year, which account for 12 to 18 % of their total food expenses. However, fish species consumption preference varies for different income groups. The groups with higher income prefer higher value fish species. Those in the high income class are mainly consuming common carp, while those in the middle and low income class are consuming Indian carps and Chinese carps, respectively.

Table 4 shows the price and expenditure elasticities of some major fish group in Vietnam. The own-price elasticities are all negative and highly elastic with the exception of other fish group. These indicate that when the prices of these fish increased, consumers will consume less. The positive cross price elasticities indicate that these fish groups are substitutable. While, the expenditure elasticity are positive for all fish groups, reflecting that when consumers have more income they will consume more fish. Thus, the demand of fish is expected to increase as income of Vietnamese is increasing. The expenditure is elastic for Indian carps and other fish groups and inelastic for tilapia and Chinese carps. This implies that consumers prefer spending their income in consumption of Indian carp (rohu and mrigal) and other fish groups such as grass carp, pangasius and silver barb etc.

Table 4: Price and expenditure elasticities of four fish groups in Vietnam

Fish group	Chinese carp	Tilapia	Indian carp	Other fish	Expenditure
Chinese carp	- 1.934	0.345	0.565	0.480	0.478
Tilapia	0.248	- 1.4.38	0.260	0.157	0.947
Indian carp	0.394	0.223	- 1.712	- 0.479	1.104
Other fish	0.266	0.120	- 0.464	- 0.961	1.081

EXISTING RESEARCH IN SOCIOECONOMICS OF CARP CULTURE

As mentioned earlier, in the Red River Delta of Vietnam, an integrated farming system the so-called VAC system has been widely practiced. In recent years, VAC (family food production) system research programme including gardening, livestock and fish culture is being conducted by the Research Institute for Aquaculture No.1 (RIA No.1) with the collaboration of Asian Institute of Technology (AIT) Aqua-Outreach Programme in the Red River Delta. The institutions involved are RIA No. 1, Hanoi Agricultural University and the University of Hanoi. The results obtained is building up improved and advanced VAC models in the Red River Delta.

FUTURE RESEARCH NEEDS

It is necessary to improve carp seed quality through selective breeding programmes and to promote sustainable yields of carp in semi-intensive culture system. Studies have to be undertaken to analyse constraints to increasing carp productivity and to prioritize breeding goals with due consideration of equity and sustainability issues.

ANNEX 4

Documentation of Carp Genetic Resources in Asia

DOCUMENTATION OF CARP GENETIC RESOURCES IN ASIA

OBJECTIVES

(1) Systematic documentation of carp genetic resources and their evaluation and utilization in aquaculture in the six developing countries of Asia. (2) The final output will be a book "Carp Genetic Resources for Aquaculture in Asia". The contributing country representatives will share in recognition and authorship.

FRAMEWORK, PROTOCOL AND FORMAT

The representatives at the committee meeting expressed concern that the potential volume of information would result in an unmanageable exercise with the time and resources available. Therefore, members of the committee decided that:

1) Each country would prioritize the species for which they would submit information. The basis for prioritization and factors that should be included in the decision process are a) past, present and future aquacultural importance, b) availability of genetic information, c) species that best meet the overall project objective to improve and best impact the availability of fish to low income consumer and increase farming production and profits for low income farmers, particularly female farmers, if possible, c) although the decision was reached to prioritize the species included in this documentation, there obviously is no limitation in the number of species that can be included by each country if the individual contributors have the energy to make this document as thorough as possible.

2. Sources of information

Information for the documentation should come from all available published sources. This includes indigenous published knowledge, especially documents that include comparative genetic data on aquaculture performance data such as growth, feed conversion efficiency, survival, disease resistance, tolerance of environmental factors a such as low oxygen, high ammonia, high nitrite, temperature and salinity, harvestibility, body shape, dressing percentage, body composition, carcass quality, and reproductive performance such as age at maturity, spawning date-temperature, standardized fecundity (eggs/kg), percentage of individuals spawning and hatchability.

3. Form of submitted information

If possible, the information should be submitted as a windows 6 file. Second choice is an ASCI file.

4. Format and information to be included in the submission

The formatted information should be submitted by species and by section.

Section-I BIOLOGY OF THE SPECIES

A brief biological description should be included which contains general information such as taxonomic status of the species, its general characteristics and its distribution. This probably does not need to be more than a page for each species. Several contributors already have a good start on this part and the information is included in the reports that were brought to the meeting. Examples are the introductory and background information in the reports provided by Thailand, Bangladesh and China and the souvenir publication for the member provided by India.

Section-II STATUS OF THE GENETIC EVALUATION, GENETIC IMPROVEMENT AND UTILISATION OF DIFFERENT GENOTYPES OF CARPS (INDIAN, CHINESE, COMMON CARPS AND SILVER CARPS etc.)

This is the most critical section of the documentation. The greatest amount of effort should be expended for this section and it should have the greatest priority for completeness as compared to the other sections. Experiments involving aquaculture production traits should be emphasized and should be the top priority.

a) Each experiment or paper's details should be briefly described as follows:

1. Where and when was the evaluation or comparison was conducted;

2. Describe the experimental conditions and units, i.e. ponds, tanks, monoculture, polyculture, farming systems, feed type and density;

3. The genotypes or genetic groups evaluated or compared, for example, the population, stocks, strains (in these cases were they wild or domestic genotypes), selected lines, inbred lines, families, intraspecific crossbreeds, interspecific hybrids (F_1, F_2, F_3, backcross etc.), mitotic gynogen, meiotic gynogen, androgen, triploid, tetraploid, sex, sex reversal genotype, nuclear transplanted hybrid or transgenic genotype and control genotype;

4. Where and when did the genotype or genetic group originate;

5. Traits or characteristics measured;

6. Results: In the case of small experiments this might be submitted as text or in the case of big experiments this might be submitted in tabular form. Any significant difference should be indicated.

7. Present location of the genotype or genetic groups evaluated or compared, do they still exist? If so, at research institution(s), at government hatcheries or farms?

Section-III: UTILIZATION OF GENETIC RESOURCES

Part of utilization of genetic resources is found in section II. Additional pertinent non-comparative information might be available.

1. Examples of genetic breeding programs at hatcheries or farms. This should be of high priority for documentation. Other information that would be of lower priority for documentation;

2. Effective population sizes of known populations or genetic groups;

3. Brood stock structure (year classes, generations, sex ratios and number) in known populations or genetic groups.

Section IV: DOCUMENTATION OF GENETIC RESOURCES IN CARPS

This is probably the second most important section and should receive the second highest level of effort for documentation and reporting. Location and status of the existence of the population or genetic groups from which the gene resource information is derived should be included in the information provided.

a) Molecular gene resources

1. Known genomic libraries
2. Known isolated carp genes including structural genes and regulatory regions such as promoters and enhancers;
3. Known gene maps, linkage groups or linkage relations for carps;

b) Quantitative Gene Resources - Information for production traits should be emphasized:

1. Heritabilities;
2. Genetic correlations
3. Phenotypic variances

c) Qualitative Gene Resources

In cases where information on quantitative traits of commercial or economic importance such as color, deformities, etc., is available, the inheritance such as dominance, recessiveness, epistasis, partial dominance, over dominance, pleiotropy, simple additivity, should be indicated.

Section V: GENETIC CHARACTERIZATION OF POPULATIONS OR GENETYIC GROUPS

The third highest level of effort should be devoted to documentation in this section, again description of the origin, location and current status of existances for the population on genetic groups surveyed needs to be provided. Tables or text should be generated indicating allele frequencies, heterozygosities, alleles per locus and percent loci polymorphic.

Studies examining the following genetic parameters could be included:

1. Isozymes
2. Isoelectric focusing products
3. Immunological markers
4. Blood types and Hbg
5. Molecular markers
   a) mtDNA
   b) RFLP
   c) DNA fingerprints
   d) microsatellites
   e) RAPD
   f) AFLP
   g) EST

Studies examining interspecific differences should be included because of their value in hybrid and species identification.

Section-VI: CYTOGENETICS OF CARPS

This section should have the least amount of effort expended. Location and present status of the population from which this species information is derived should be included in the information provided.

Descriptions to include:

1. Karyotypes descriptions, chromosome number
2. Banding
3. NORs
4. FISH
5. Arm numbers and chomosone type
6. Genotoxic data

RATIONALE FOR PRIORITIZATION OF SECTIONS

Since the committee decided that the documentation and description of an unabridged set of information on carp genetic resources may not be feasible, high priority sections were those most likely to provided information that would allow immediate or short term genetic improvement, and those sections providing information that would yield long term genetic improvement were given a lower priority. If the energy level allows thorough documentation of all sections, information will not be rejected.

REFERENCES

A reference list should be included for all information provided. Full citations using the format of the journal Aquaculture, should be included. A second list of references should be provided for other published sources on carp genetics that were not included in the descriptions in the sections due to the time limitations.