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Alternate carp species for diversification in freshwater aquaculture in India

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Indian fisheries has made great strides during last five decades with the production levels increasing from 750,000 tonnes of fish in 1950-51 to 6.4 million tons in 2005-2006, of which the contribution from the inland sector is around 3.3 million tons (51.6 % of the total) compared to 3.10 million tons (48.4 %) from the marine sector. The contribution of fisheries to the gross domestic product (GDP) and agriculture GDP has been estimated to be 1.2 and 4.2 %, respectively. India ranks second in world inland fish production, next to China. The growth rate of inland and marine sector at present is 6.6 and 2.2%, respectively. The anticipated growth rate during the tenth five-year plan (2002-2007) for inland and marine fisheries are 8.0% and 2.5 %, respectively.

Indian freshwater aquaculture has evolved itself from the stage of a domestic activity in the Eastern States of West Bengal and Orissa to that of industry and has become an important component of Indian fisheries contributing about one third of total fish production of the country and share about 95% of the total aquaculture production. The mean national fish production levels from tanks and ponds have increased significantly from 600 kg/ha during the 1970's to 2,200 kg/ha in the 1990s. In some areas such as the states of Andhra Pradesh, West Bengal, Punjab and Haryana yield has increased even to 8,000-10,000 kg/ha. Demonstrations on intensive composite carp culture practices had shown a maximum production of 15,000 kg/ha at Central Institute of Freshwater Aquaculture, Bhubaneswar (Jana and Jena, 2004).

Carps are the backbone of Indian freshwater aquaculture, comprising around 85% of the total freshwater production. Carp culture in India is largely limited to six species; the three Indian 'major carps' catla, rohu and mrigal; and three exotic or 'Chinese carps', grass carp, silver carp and common carp. Again, Indian major carps contribute the lion's share of freshwater aquaculture production, around 80% by volume. Among Indian major carp production, the contribution of rohu alone is about 35%.

India is regarded as a 'carp country' due to its rich diversity of carps in its freshwater ecosystems. About 2,070 species of carps (family Cyprinidae) are available in Indian waters. Though many of the carp species like minor barbs and minnows are not economical from the commercial culture point of view, the country is blessed with at least 15-20 varieties of minor and medium carps that have a high potential for freshwater aquaculture, which has yet to be exploited. These carp species can be considered as alternatives to the major cultured carp species, for diversification in freshwater aquaculture. The systematic classification, geographical distribution, biology, age at sexual maturity, breeding behaviour, consumer preference, present culture status, problems and prospects of culture along with the suggestions for conservation of these species are detailed below.

Labeo calbasu

Commonly called 'kalbasu', or 'black rohu' in some areas, it is a carp of medium economic significance, though some authors categorized it as major carp. It belongs to the sub-family Cyprininae. *Labeo calbasu* is widely distributed in India. It is a highly preferred food fish. It is also considered as a game fish. It can be domesticated in tanks and is suitable for composite fish culture with other carp species. It thrives well in tanks, lakes and other forms of stagnant water bodies. It is an 'illiophage', predominantly herbivorous, feeding on the bottom. Kalbasu competes with mrigal, frimbritus and bata in culture environments. Its feed mainly consists of organic detritus, diatoms and green algae along with zooplankton. Kalbasu has comparatively few inter-muscular bones than the major carps. It is a seasonal breeder and spawns once per year in lotic environments during the monsoon. It can be induced to breed by hypophysation. The relative fecundity of Kalbasu is highest among all major carps, ranging from 90,000 in first year group to over 500,000 in seventh year class. It can reach a maximum length of around 100 cm, but grows to around 20cm and 800 g in the first year. Sexual dimorphism is more prominent during breeding season. Like major carps, the male develops roughness on the pectoral fin and a sandy texture on scales and milt oozes with slight pressure on abdomen. In the case of females, the pectoral fins and scales are found to be smooth, abdomen bulges and the vent appears reddish and protrudes outside. Using induced breeding techniques, Kalbasu

can be bred twice or three times in a breeding season. The average diameter of the matured egg is 1.5 mm. The incubation period is around 15 hours. The growth rate of females is slightly better than males. *L. calbasu* is being cultivated along with Indian major carps in eastern India.

Labeo fimbritus

A 'medium carp', which grows to a medium size. It is commonly called the "fringe-lipped peninsular carp", and is widely distributed throughout central and peninsular India. It is suitable for cultivation in confined waters. It is a bottom dweller, preferring the sandy bottom of the river, but often wanders in the column water in search of food. It is mainly available in the Krishna, Godavari, Tungabhadra, Mahanadi, Narmada, Cauvery and Tapti river systems. It is the basis of a major fishery in the Narmada river system, where is popularly called the 'rohu of the Narmada river' by consumers. This species is a herbivorous bottom feeder, consuming mainly vegetable debris, decaying organic matter, algae (Chlorophyceae and Myxophyceae) and macro-vegetation in adult stages and the planktonic crustaceaens, protozoa, rotifer, copepod and Bacillariophyceae in fry and fingerling stages. In adult fish, the lip is thick, continuous and fringed with a thin cartilaginous layer on the inner side of both jaws. Like other carps, sex is easily recognized during breeding season. It matures in the second year of life and breeds during the monsoon season. The female generally attains first maturity at 40-50 cm length. It is a highly fecund fish and the fecundity varies from 100,000 (in the first year age group) to 500,000 (in seventh year age group). In nature, it can grow over 60 cm and 3.15 kg. But in ponds it can grow to around 23 cm and 450 g in the first year and 31 cm in the second year, so it is a relatively slow growing fish. It can be cultured with other major carps in pond. The eggs of the fish are non-adhesive, demersal, transparent and round. The diameter of a fully swollen egg is reported to vary from 3.5-6.0 mm. Although the fish has high potential for composite culture along with other carps, so far it is not being cultured commercially in India.

Labeo bata

A minor carp commonly known as 'Bata'. It is distributed throughout northern India. It is also found in the Cauvery, Krishna, Godavari river systems of peninsular south India and the freshwater bodies of West Bengal, Orissa, Uttar Pradesh, Bihar and Assam. They are also available in the upper stretches of the Ganga, Yamuna and Bramhaputra rivers. *L. bata* is considered an esteemed food fish and cultured along with other major carps in India. It is found in tanks, rivers, reservoirs, jheels, beels and moats. Until now the major source of seed for culture of this species has been wild collection from river, reservoir, and wet bundhs. It attains a length of 20-25 cm in pond and 40-60 cm in large tanks and reservoirs. It is also a slow growing fish, reaching 20-22.5 cm length in 9-10 months, and the growth rate of this species decreases markedly after two years in age. *L. bata* is herbivorous, adults are bottom dwellers but frequently move in all zones of the water column for feeding and breeding purposes. It generally matures in two years but under favourable conditions it can mature in the first year. Fully matured fish are found in May-June. The average length of the matured fish in both sexes is around 20 cm and 100-125 g in weight. They are also highly fecund ranging from 300,000 to 450,000 eggs per kg body weight. *L. bata* breeds early in the monsoon and its spawning season is very short. In nature it spawns once in a year but by induced breeding it can be made to spawn 2-3 times in a year. The diameter of the fully swollen egg is 3.0-3.5 mm. Although it is a tasty fish, the fine inter-muscular bones dampen its preference among consumers. It is relatively susceptible to even slight adverse water quality when compared to major carps and cannot withstand long distance transportation even under normal oxygen packing. It is widely cultured in bheries in the Sunderban areas of West Bengal.

Labeo gonius

A medium carp, popularly called 'kuria labeo; or "gonius", it is is distributed in Bengal, Orissa, Assam, Uttar Pradesh, Bihar, Rajsthan, Madhya Pradesh and Punjab in the major freshwater rivers, reservoirs, lakes, jheels and tanks. It is the slowest growing among the potentially cultivable carps. The average size at maturity is around 300-500 g. The maximum reported size of *L. gonius* reported is 150 cm (Day, 1878), however around 50 cm is more typical of commercial catches. In one year it can reach 40 cm and 750 g. It is also a high fecund fish like rohu, ranging from 245,000 (800-900 g fish) to 540,000 (1.5- 1.6 kg fish). Eggs are demersal, non-adhesive, transparent and round. The diameter of a fully swollen egg ranges from 2.8 – 4.5 mm. The size on first maturity varies from 14–23 cm in males and 18–30 cm in females in different freshwater ecosystems. The males attain maturity earlier then females both in terms of age and size. In nature, the usual maturity age is three years; however pond reared fish can mature even in one year. Peak maturity is found in May-June. All ova are shed during single spawning act. It can be induced to breed with pituitary injection. *L. gonius* is a herbivorous bottom feeder and in composite fish culture it competes with mrigal, calbasu, fimbriatus and bata. Excepting for Assam, it is not considered as an important culture fishery in India. In Assam, as mrigal is not consumed due to some religious belief, *L. gonius* is cultured instead as a bottom feeding substitute in composite fish culture.

Labeo kontius

Commonly known as 'pig mouth carp', *L. kontius* is a valuable component of capture fisheries in the Cauvery River system, found specifically in the middle and lower stretches of the river. Although it is found in certain areas of South India, it is not available in the Gangetic belt. It is predominantly herbivorous and can be domesticated for pond culture. It has a peculiar feeding habit, in that the adult and fingerling being bottom and column feeders, while the spawn and fry stages feed in the surface realm. The fish is found to be very active and hardy. It can jump up in the air in their attempt to negotiate the barriers found in the river and move upstream. It breeds once per year during the monsoon season in June–August. Breeding occurs during both day and night. The information regarding the fecundity of this species is lacking. Fertilized eggs are demersal, non–adhensive, round and transparent with pale–blue colour. The fully swollen eggs are 3.5 – 4.3 mm in diameter. It is a slow growing fish, which can grow up to 23 –30 cm in length and 350 g in weight at the end of the first year in ponds. It becomes sexually mature at

30-35 cm length. It is currently being cultivated in ponds of South India particularly in Tamilnadu and Karnataka.

Labeo dero

It is a minor carp and forms a commercially important food fish in upland waters in Northern India. This fish is commonly known as "Kursa Bata". Flesh of this fish is well flavoured and highly esteemed as food. It is widely distributed all along the Himalayan rivers particularly in the Sutlej, Beas, Ravi, Baner, Tawi and Jhelum. It is mainly restricted in the upper reaches of the river. The fish prefer to come down to lower stretches of the river to avoid the cold during winter months. It is distributed mainly in the States of Arunachal Pradesh, Punjab and Jammu and Kashmir. It is also observed in the Mahanadi river system in Orissa. It is a herbivorous fish, feeding on soft aquatic vegetation and periphyton. It also feeds by licking off algal growth from rocks and hard surfaces. It is highly fecund ranging from 67, 288 (330 g fish) to 700,000 (1.35 kg fish). It breeds early during the monsoon over a very short breeding period. It is relatively slow-growing, reaching a maximum size of 1.5 kg in weight and 50 cm in length. The fertilized eggs are non–adhesive, demersal and 2.9 – 3.2 mm in diameter. Culture and seed production of this fish is not being realized in India till now.

Labeo dussumieri

L. dussumieri is a medium carp, and the only member of the *Labeo* genus that is found indigenously in south India particularly in Kerala. It is an endangered species. The fish is variously known as 'Malabar Labeo', 'Thooli' and 'Pullan'. It is restricted to Kerala in the Pampa, Manimala and Meenachil rivers. It can grow up to 35 cm. Fecundity is low compared to the other carp species, ranging from 65,000 to 240,000 for a fish of 35-45 cm. Very few attempts have been made to study the biology, feeding habit, breeding and culture aspects of this species.

Labeo boggut

A minor carp, commonly known as 'Boggut Labeo'. It is the most slender fish among the genus *Labeo*. It is distributed in Northern India and the Cauvery River system. A fairly large quantity of this species is also available in Panna weekly market of Madhya Pradesh. It is abundantly available in Kathiawar Island watershed of Gujarat. This species is also available in the Krishna and Tungabhadra watersheds. The sexual maturity of the fish occurs at 14-15 cm length. It is a monsoon breeder. Ripe females are observed in June-July. Not much work has been carried out on the breeding habit of this fish.

Cirrhinus reba

A minor carp commonly known as 'Reba carp'. It is a widely distributed in India, found in the Gangetic regions in North and Cauvery River systems in South, although it is not available in the Malabar River systems. It is a bottom feeder and prefers to stay in deep water. It is predominantly a plankton feeder in young stages and takes on a herbivorous habit in adult stages. The fish attains sexual maturity after one year at 22-25 cm in length. Induced breeding through hypophysation has been attempted on the species. Although the breeding season extends from May to October, the peak breeding occurs in June-August. The fecundity of the fish is 287 egg/kg body weight. The initial growth rate of the fish is very fast, even greater than catla, though fish does not grow beyond 30 cm in ponds. No attempts have been made for commercial scientific culture of this species in India.

Cirrhinus cirrhosa

A medium carp commonly known as 'white carp'. It is widely distributed in southern Indian rivers. Cauvery is called the 'river of white carp'. It is also available in the Krishna, Godavari, Narmada and Pench river systems. It is a very active fish and can swiftly swim against the current. It is a bottom feeder. The young fish feeds on zooplankton whereas the adult prefers phyto-plankton. It matures in the first year at a size of 20-25 cm. The breeding season is from July-September. It does not breed in confinement but can be domesticated in ponds. The fecundity of the fish is 150,000-200,000/kg fish. The eggs are spherical, non-adhesive and demersal. Although the fish is a tasty one, the flesh contains more bones. In India, no attempt has been made for commercial seed production and culture of this species.

*Barbonymus gonionotus**

A medium carp, and exotic to India, having been introduced to India in 1972 to control aquatic weeds. It is commonly called 'silver barb', 'Thai barb', 'Java carp', 'tawes' and 'Raj punti'. The fish is an omnivore, but prefers to eat soft weeds like *Hydrilla*, *Najas*, *Ceratophyllum*, etc. It is a column feeder and can compete with rohu in composite fish culture. Sexual maturity is attained in 8-10 months in females and 6-8 months in males. The fish can grow 700-800 g/year in a culture pond. The initial growth rate of the fish is as fast as Indian major carps. The marketable size of this fish is over 300 g. Females generally grow faster than males. It is an auto-breeder and breeds in confinement. It can also be induced bred using synthetic hormone and pituitary extract. The fecundity of this fish is 300,000-500,000 egg/kg body weight. The size of the egg is small (0.98 mm). Although the fish was introduced in the 1970s, the culture potentiality of this species was only realized during the late 1990s. The fish is now already being cultured in West Bengal, Assam and other northeastern states. It is a highly preferred fish and fetches the same market price as that of Indian major carps.

Puntius sarana

A minor carp that is an esteemed food in eastern region of the country. It is commonly known as "sarana" or "sar-punti". It is distributed in the Gangetic river system. It is an omnivore and eats submerged vegetation and molluscs. One peculiar feature of this species is that the rate of feeding is maximum during the peak breeding season of the fish. The fish sexually matures at the end of first year at 17-25 cm in size. It is a pre-monsoon breeder and spawns only once a year. The fecundity of the species ranges from 60,000 to 225,000 depending on the size of the fish. The fish doest not grow beyond 30 cm length and 800-900 g weight. It is exclusively freshwater and cannot withstand even very low-saline water. It dies immediately in any adverse physiological condition of soil or water. It is also easily susceptible to protozoan diseases.

** = Puntius gonionotus.*

*Hypselobarbus pulchellus***

An endangered medium carp of peninsular India, commonly called 'peninsular carp'. It is distributed in the peninsular rivers including the Krishna, Godavari and Tungabhadra. It is a herbivorous fish and changes its feeding habits depending up on the availability of food. It feeds on soft vegetation preferably *Vallisneria*. The fish attains sexual maturity at the end of first year when it grows to about 17-25 cm. It is a post-monsoon breeder and the breeding season is from July to November. It is reported that it can grow up to 6 kg in nature. Some attempts have been made to culture this species at the Peninsula Aquaculture Division of Central Institute of Freshwater Aquaculture, Hessarghata, Bangalore.

Thynnichthys sandkhol

It is a medium carp and resembles as silver carp. It is commonly called as "sandkhol carp". It is distributed in the Krishna, Godavari, Tungabhdra and Mahanadi River systems in India. It is a column-cum-surface feeder and a planktophagus fish. The fish attains sexual maturity in first year at 30 cm in length and 500 g in weight. It is a monsoon breeder and breeds once per year and does not breed in confinement. The fecundity of the fish is about 125,000/kg body weight. The initial growth rate of the fish is fast and it can grow to 0.9-1.4 kg in 9-12 months. Although a potential culture species, no attempt has been made to breed and culture on a commercial scale.

Prospects of culturing the alternate carp species:

- Except for *Cirrhinus reba* and *Puntius sarana*, all other species described are hardy in nature.
- Many of the minor and medium carps fetch better prices than the Indian major carps in different parts of the country.
- They are high fecund fish.
- The initial growth rate of many minor and medium carps is fast, being advantageous in short duration culture in seasonal water bodies.
- The marketable size of the fish is small (100-300 g) compared to 700-800 g in major carps.
- Many have prolonged breeding seasons.
- Compatible to Indian major carps for composite fish culture.
- Suitable for integrated fish culture systems (rice-fish, poultry-fish, pig-fish, cattle-fish, etc.).
- Can be cultured in low water depth, as they are hardy.
- Two crops/year can be easily harvested.
- Suitable for high stocking density culture.
- They can be cultured in pens and cages.
- Most of them are omnivores/herbivores and can easily digest the plant protein source. Therefore, the different plant based agro-industry by-products, which are rich in protein and are abundantly available in our country, can be used for low-cost feed formulation of these species.
- Can be easily domesticated to the pond environment.
- They are easily adaptable to artificial feed.
- Some of the species like *B. gonionotus* may be cultured in inland-saline areas of the country, as it can tolerate up to 8 ppt saline water.
- As they are suitable for short duration culture, farmer can get his returns in a shorter duration as compared to Indian major carps.

Problems in culturing the alternate carp species:

- Most of these carps grow slow after 4-5 months of culture and are not economical for long duration culture.
- Most the minor and medium carps lay eggs that are small in size and are transparent, posing some problem for commercial seed production.
- Although the fecundity of the fish is high, the survival rate of larvae is low under natural conditions.

Suggestions for culture expansion of alternate carp species:

- Exploratory survey are required to know the present status of these carp species in different freshwater systems of the country.
- Recording of catch statistics of these fishes is required as a priority.
- Detailed study on the biology and breeding behaviours of those species on which such information is lacking should be taken up.
- Seed production technology must be standardized to provide sufficient seeds to the farmers desirous of culturing these species on commercial scale.
- Standardization of culture techniques of these valued species is essential for encouraging farmers to take up culture of hitherto new but economically important species.
- Research on low-cost feed formulation for these species needs immediate attention, as no attempts has been made so far.
- Farmers should be encouraged to take up the culture of small and medium carp in the form of monoculture or composite fish culture.
- Horizontal expansion for the culture of these species are required, covering both season and perennial water bodies which are unutilized at present.
- More research and development is required to improve the growth of fish through hybridization or genetic improvement.

** = *Puntius pulchellus.*

Conservation measures for alternate carp species:

Some of these alternate species are endangered and some are vulnerable to extinction. To conserve these valued carp species, it is important to ensure the following measures:

- Regulation of mesh size to prevent the catching of brooders and young ones during the breeding and larval rearing stages of fish.
- Declaration of sanctuaries in the area where these species are endemic.
- Artificial recruitment may be made to revive the carp species in the areas where these fishes are less available and the catch is declining.
- Prevention of entry of industrial pollutants in the areas where these fish inhabits.
- Public awareness is required to save these fish from extinction.
- Conservation of gametes through gene banking is important for adopting future strategies of replenishment and stock enhancement of these valued carp species.

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Genetic and reproduction technologies for enhanced aquaculture and fisheries management of Murray cod

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Introduction

Fish consumption forms an important aspect in the traditional diet of many communities, particular in Asia. However, increasing consumption of seafood combined with the increasing world population has lead to a substantial rise in demands for aquatic food resources. Today, around three quarters of the world's fish stocks monitored by FAO are fully exploited, overexploited or depleted. The maximum wild capture fishery potential from the world's oceans has probably been reached and there is world-wide over-fishing of inland fishery resources. (FAO 2007). One possibility for alleviating pressure on wild fisheries is through aquaculture (food fish and aquatic plants) which continues to grow rapidly globally (average 8.8% per annum since 1970), more so than for capture fisheries (1.2%) and terrestrial farmed meat production (2.8%) (FAO 2007). Aquaculture is providing an alternative supply pathway by producing both staple fish species and high-value seafood from sustainable production systems and is alleviating pressure on wild fisheries.

In recent decades there has been a revolution in application of genomics and gene-related biotechnology in agriculture and aquaculture (eg. Foresti 2000, Hew and Fletcher 2001, Melamed et al. 2002). Biotechnology research aims to increase production and reduce costs, especially through the manipulation of the genes and chromosomes of cultivated species. Equally biotechnology is also applied to wild fisheries resources to improve their management, for example DNA is being used to differentiate populations and to manage captive breeding programs for stock enhancement/replenishment.

In Australia, through a major project funded by the State Government of Victoria, a biotechnology approach for enhancing aquaculture and fisheries management is being applied to Murray cod (*Maccullochella peelii peelii*) (Percichthyidae) (Ingram et al. 2005b, Rourke et al. 2007a, Ingram 2007). The challenge of this project is to apply advanced genetic and reproduction technologies to this high-value inland species to increase production efficiencies and manage wild populations. With gains in production performance, reliability and profitability, the next five to 10 years could see the expansion of Murray cod farming sector in Australia and internationally. Application of these technologies will also provide extra benefits for the management of native finfish biodiversity, particularly for species such as Murray cod which are declining in the wild and yet continue to be managed for multiple purposes (ie. commercial, recreation, conservation). This article outlines progress made in the project.

Murray cod, Australia's largest indigenous freshwater fish, is an iconic species with significant commercial, recreational, conservation and cultural value (Figure 1). However, over-fishing, habitat loss and modification within the cod's natural range in