**Understanding the Biology of Indian Major Carps: Key Insights for Sustainable Aquaculture and Conservation**

**Gyan Chandra, Rupam Samanta, Anjali Pushp, Naresh Raj Keer**

Department of Fisheries Resource Management,

College of Fisheries, Kishanganj-855107,

Bihar Animal Sciences University, Patna, India.

**Abstract:**

Indian major carps (catla, rohu and mrigal) are a cornerstone of India's aquaculture industry, supporting millions of livelihoods and contributing significantly to the country's food security. The major Indian carp species contribute 70 to 75% of freshwater fish production. These carp species have diverse biological profiles adapted to specific environmental niches. Reproductive biology is critical for the sustainable management of these carp species, as it impacts aquaculture practices and natural habitat conservation. Conserving these carp species in fragile ecosystems faces challenges like overfishing, habitat degradation, water pollution, illegal fish introduction, and the impacts of climate change. A holistic approach combining habitat restoration, sustainable fishing practices, and community engagement is essential to mitigate these challenges. Taxonomy, classification, and distribution are fundamental for sustainable fish resource management and conservation. Accurate species identification and understanding of taxonomic relationships are vital for informed decision-making in aquaculture. Induced breeding is a widely used method for carp seed production, involving hormonal stimulation with pituitary extract or synthetic formulations. The Chinese circular hatchery system is efficient for large-scale production, with a two-tier rearing system involving a nursery and fingerling phase. In conclusion, Indian major carps are significant for India's food security and the aquaculture industry. Understanding their biology, ecology, taxonomy, and reproductive processes is essential for conservation and sustainable aquaculture practices.

**1. Introduction**

The Indian major carps include catla (*Labeo catla*), rohu (*Labeo rohita*), and mrigal (*Cirrhinus mrigala*), and are known for their culinary appeal and also serve as a cornerstone of India's aquaculture industry. It supports millions of livelihoods and contributes significantly to the country's food security. On a global scale, India ranks second in aquaculture. Despite having a fifth of the world's population, China manages to produce one-third of the entire fish harvest and cultivates two-thirds of the fish. Over the past two decades, Indian aquaculture has grown rapidly, expanding by six and a half times. Freshwater aquaculture has played a pivotal role, contributing over 95% of the total aquaculture production. India is endowed with an extensive aquatic resource base, encompassing 3.15 million hectares of reservoirs, 2.36 million hectares of ponds and tanks, and 0.19 million hectares of rivers and canals. In the mid-1980s, freshwater aquaculture represented only 34% of inland fisheries, but its share has surged to approximately 80% in recent years. The adoption of technologies such as induced carp breeding and polyculture in ponds and tanks has driven significant improvements in aquaculture productivity, transforming the sector into a rapidly growing industry. Carp culture, specifically the polyculture of three Indian major carps - catla (*C. catla*), rohu (*L. rohita*), and mrigal (*C. mrigala*)as well as the composite culture of these species with three exotic Chinese carps (grass carp, silver carp and common carp) constitutes the prevailing practice. Among these, the three major Indian carp species contribute 70 to 75% of the total freshwater fish production, while the exotic carp species make up the remaining 25 to 30%.

Indian major carps are characterized by their diverse biological profiles, each adapted to specific environmental niches. The catla, for instance, is known for its surface-feeding habits and rapid growth rates. In contrast, the rohu is a column feeder, while the mrigal exhibits bottom-feeding habits. Understanding these distinct ecological niches and feeding behaviours is essential for successful aquaculture and habitat management. The reproductive strategies of these carp are of paramount importance for their sustainable management. Knowledge of reproductive biology is crucial for successful aquaculture practices and effective conservation in their natural habitat. Genetic diversity within Indian major carp's populations is critical for their resilience to changing environmental conditions and disease resistance. Maintaining and conserving this genetic diversity is essential for the long-term sustainability of these important species. Furthermore, ongoing carp genetics and genomics research provides valuable insights into selective breeding programs to improve growth rates, disease resistance, and overall aquaculture productivity. Conserving Indian major carps in fragile ecosystems faces several challenges. In general, overfishing, habitat degradation, and water pollution are significant threats to fisheries resources around the globe. Additionally, the introduction of non-native species and the impacts of climate change further complicate conservation efforts. Therefore, a holistic approach that combines habitat restoration, sustainable fishing practices, and community engagement is essential to mitigate these challenges. Sustainable aquaculture practices are vital for the conservation of Indian major carps and the economic well-being of those involved in the industry. Innovations such as integrated multitrophic aquaculture (IMTA) and environmentally friendly feed formulations can minimize the environmental footprint of carp farming. Furthermore, the adoption of responsible and ethical farming practices can enhance the reputation and marketability of Indian major carp's products. In conclusion, Indian major carps are not just a source of nutrition and livelihood but also hold cultural significance in India. Understanding their biology and ecology is central to their conservation and sustainable aquaculture. This book chapter will delve deeper into these aspects, drawing upon the latest research and insights to provide a comprehensive overview of the Indian major carps and the strategies needed to ensure their enduring presence in India's aquatic ecosystems.

**2. Taxonomy, Classification and Distribution**

Taxonomy is a fundamental tool for the sustainable management of fish resources, the conservation of aquatic biodiversity, and the successful operation of aquaculture facilities. Accurate species identification and understanding of taxonomic relationships are essential for making informed decisions in these fields. Taxonomy plays a pivotal role in aquaculture by enabling precise species identification, which is essential for the efficient management of fish stocks and resources. It guides selective breeding programs by identifying genetically desirable traits and improving production efficiency. In disease management, taxonomy helps assess species susceptibility and implement appropriate preventive measures, safeguarding the health of aquaculture populations. Additionally, taxonomy is crucial for biodiversity conservation efforts, aiding in the protection of endangered or threatened fish species and their habitats. It supports ecosystem monitoring by providing a framework for assessing changes in species composition and distribution. Accurate taxonomy also facilitates adherence to regulatory measures governing catch limits and size restrictions, ensuring the sustainability of fisheries and aquaculture practices. Overall, taxonomy is an indispensable tool for both the economic success and environmental responsibility of fish-related industries.

***Labeo catla***

*Labeo catla*, commonly known as the catla, a freshwater fish belonging to the family Cyprinidae. Catla is endemic to the riverine system in northern India, the Indus Plain and adjoining hills of Pakistan, Bangladesh, Nepal and Myanmar, and has been introduced later into almost all riverine systems, reservoirs and tanks all over India. The natural distribution of catla seems to be governed by temperature dependency rather than latitude and longitude. The minimum tolerance temperature limit is ~14 °C. The use of catla as a component in pond culture was a traditional practice in the eastern Indian states, spreading to all other Indian states only during the second half of the 20th century. The growth rate of catla and its compatibility with other major carps, specific surface feeding habits, and consumer fondness have increased its popularity in carp polyculture systems among fish farmers in India, Bangladesh, Myanmar, Laos, Pakistan and Thailand. The species has also been introduced elsewhere, including Sri Lanka, Mauritius, Japan, and Israel. At present, catla is an integral component species, both in a three-species polyculture with rohu (*Labeo rohita*) and mrigal (*Cirrhinus mrigala*) and six-species composite carp culture, which adds common carp (*Cyprinus carpio*), grass carp (*Ctenopharyngodon idellus*) and silver carp (*Hypophthalmichthys molitrix*) to the culture system.

Identifying biological characteristics

Body short and deep, somewhat laterally compressed, its depth more than head length; head very large, its depth exceeding half the head length; body with conspicuously large cycloid scales, head devoid of scales; snout bluntly rounded; eyes large and visible from underside of the head; mouth wide and upturned with prominent protruding lower jaw; upper lip absent, lower lip very thick; no barbels; lower jaw with a movable articulation at symphysis, without a prominent process; gill rakers long and fine; pharyngeal teeth in three-row, 5.3.2/2.3.5 pattern; dorsal fin inserted slightly in advance of pelvic fins, with 14 to 16 branched rays, the simple rays non-osseous; anal fin short; pectoral fins long extending to pelvic fins; caudal fin forked; lateral line with 40 to 43 scales. Greyish on back and flanks, silvery-white below; fins dusky.

Taxonomic classification

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| --- | --- |
| Kingdom | Animalia |
| Phylum | Chordata |
| Class | Actinopterygii |
| Order | Cypriniformes |
| Family | Cyprinidae |
| Genus | Labeo |
| Species | *Labeo catla* |

***Labeo rohita***

*Labeo rohita*, commonly known as the rohu, is another species of freshwater fish belonging to the family Cyprinidae. Rohu (*Labeo rohita*) is the most important species among the three Indian major carps popularly cultured in polyculture systems of carp. This elegant Indo-Gangetic riverine fish is a resident of the riverine system of northern and central India. It is also found in the rivers of Bangladesh, Pakistan and Myanmar. This fish has been transplanted into almost all riverine systems of India, including the freshwaters of Andaman, where its population has been successfully established. Rohu has also been introduced in many other countries, including Japan, Sri Lanka, the former USSR, Malaysia, China, the Philippines, Nepal and some countries of Africa. Its high growth rate, coupled with high consumer preference, has recognized rohu as the most important freshwater fish cultured in India, Bangladesh, Pakistan and other neighbouring countries. Considering its significance in aquaculture, emphasis has been given to its genetic improvement and selective breeding programme.

Identifying biological characteristics

Body bilaterally symmetrical, body with cycloid scales, head without scale, body moderately elongate, dorsal profile of fish is more arched than the ventral profile; snout fairly depressed and projecting afar mouth, with no lateral lobe; eyes dorsolaterally placed, not noticeable from outside of head; inferior and small mouth; thick lips, characterized by lips fringed with a distinctive inner fold on each side, either lobate or entire; possessing a pair of small maxillary barbels concealed within a lateral groove; lacking teeth on the jaws but featuring pharyngeal teeth arranged in three rows; the upper jaw does not extend to the front edge of the eye; the dorsal fin has three or four simple (unbranched) rays and 12 to 14 branched rays; dorsal fin is inserted midway between the snout tip and the base of the caudal fin; both pectoral and pelvic fins are laterally positioned; the pectoral fin lacks an osseous spine; the caudal fin is deeply forked; the lower lip is typically connected to the isthmus by a narrow or broad bridge; there are 12 to 16 pre-dorsal scales; a distinct and complete lateral line runs along the median line of the caudal peduncle, with 40 to 44 lateral line scales; there are six or six and a half lateral transverse scale-rows between the lateral line and the pelvic fin base; the snout is not truncate and lacks any lateral lobe; and the coloration is bluish on the back and silvery on the flanks and belly.

Taxonomic classification

|  |  |
| --- | --- |
| Kingdom | Animalia |
| Phylum | Chordata |
| Class | Actinopterygii |
| Order | Cypriniformes |
| Family | Cyprinidae |
| Genus | Labeo |
| Species | *Labeo rohita* |

*Cirrhinus mrigala*

*Cirrhinus mrigala*, commonly known as the mrigal, a freshwater fish belonging to the family Cyprinidae. Mrigal, a carp endemic to Indo-Gangetic riverine systems, is one of the three Indian major carps cultivated popularly in many Asian countries. Mrigal has long been important in polyculture with other native species, mainly in India. However, records of its culture are available only from the early part of the 20th century. The traditional culture of the species was restricted to eastern parts of India until the 1950s. The initially higher growth rate of mrigal, coupled with its compatibility with other carps, has helped in establishing this species as one of the principal component species in pond culture. The species was transplanted in the peninsular riverine systems of India, where it has established itself. Subsequently, it has spread over the whole of India. In addition, mrigal has become an important component in the fish culture systems of Bangladesh, Pakistan, Myanmar, the Lao People's Democratic Republic, Thailand and Nepal. Mrigal has also been introduced to Sri Lanka, Vietnam, China, Mauritius, Japan, Malaysia, the Philippines and the former USSR.

Identifying biological characteristics

Body bilaterally symmetrical and streamlined, depth about equal to the length of head; cycloid scales and head lacking scales, mouth broad, snout blunt, often with pores; transverse; upper lip entire and not continuous with the lower lip and lower lip most indistinct, lone pair of small rostral barbels; three rows of pharyngeal teeth, 5.4.2/2.4.5 pattern, a lower jaw with a little post-symphysial knob or tubercle; origin of dorsal fin closer to end of snout than the base of caudal; last unbranched ray of dorsal fin is non-serrated and non-osseous, dorsal fin as high as the body with 12 or 13 branched rays; lateral line with 40-45 scales; pectoral fins smaller than head; caudal fin intensely forked and anal fin not extend to caudal fin; lateral transverse scale rows 6 - 7/5½ - 6 between lateral line and pelvic fin base; typically dark grey over, silvery underneath; dorsal fin grey; pectoral, pelvic and anal fins orange-tipped, especially during breeding season.

Taxonomic classification

|  |  |
| --- | --- |
| Kingdom | Animalia |
| Phylum | Chordata |
| Class | Actinopterygii |
| Order | Cypriniformes |
| Family | Cyprinidae |
| Genus | *Cirrhinus* |
| Species | *Cirrhinus mrigala* |

**3. Life Cycle, Reproduction and Biology**

Understanding the life cycle and reproductive processes of Indian major carps is crucial for sustainable management and cultivation. Spawning usually occurs during the monsoon season when water conditions are favourable. During this time, mature female carp release their eggs into the water, and mature male carp release sperm, known as milt, which fertilizes the eggs. This process is often triggered by environmental cues such as changes in water temperature, rainfall, and photoperiod. Unlike some fish species, Indian major carps do not provide significant parental care. Once the eggs are laid and fertilized, both the male and female carp typically move on, leaving the eggs to develop independently. Once fertilization takes place, the eggs become fertilized and develop into embryos. This stage typically lasts a few hours, during which the embryos develop inside the egg capsules. As the embryos develop, they hatch from the egg capsules, and the larvae emerge. At this stage, the larvae are tiny and transparent. They are highly vulnerable to predation and environmental conditions. To survive, they rely on their yolk sacs for nourishment initially. As the larvae grow and absorb their yolk sacs, they transition into the fry stage. Fry are small fish with developed fins and scales. They are more mobile and begin to actively swim and explore their environment. During this stage, their diet primarily consists of zooplankton and phytoplankton, which are abundant in freshwater ecosystems. With continued growth and development, the fry becomes fingerlings. Fingerlings are larger than fry and have more pronounced features. They shift their diet to include larger food items, including dead and decaying plants. This stage is crucial for their overall development and survival. The final stage of the life cycle is when the fingerlings reach adulthood. Indian major carp's sexual maturity depends on various factors, including water temperature, food availability, and environmental conditions.

Catla is a eurythermal species that thrives best at 25-32 °C temperatures. The species follows an interesting reproductive pattern where the eggs start as demersal, gradually becoming buoyant. Early-stage larvae prefer surface and sub-surface waters, exhibiting strong phototactic behaviour. These young fish feed three days after hatching while their yolk sacs are still present. As they grow, their gill rakers and gill filaments increase in number, aiding them in filtering and consuming various food items. The fry of Catla is planktophagic, mainly feeding on zooplankton like rotifers and cladocerans. Adult catla, on the other hand, primarily feed in surface and mid-waters and are also planktophagous, showing a preference for zooplankton, particularly crustaceans, rotifers, insects, and protozoa, alongside some algal and plant material. Catla typically attains maturity at around two years of age. During the monsoon season, they migrate to the upper stretches of rivers for spawning. The spawning season generally aligns with the southwest monsoon in north-eastern India and Bangladesh (May to August) and in north India and Pakistan (June to September). Catla's fecundity varies but can range from 100,000 to 200,000 eggs per kilogram of body weight. Catla is challenging to breed in captivity, as it requires specific environmental conditions for successful spawning. Under normal conditions, catla can grow up to 1-1.2 kg in the first year; rohu can grow up to 700-800 g and 600-700 g for mrigal.

Rohu is another eurythermal species that does not thrive below 14 °C. It is a fast-growing species, reaching approximately 35-45 cm in total length and 700-800 g in just one year under standard culture conditions. In polyculture settings, rohu typically exhibits a higher growth rate than mrigal but lower than catla. Rohu reaches first maturity at two years for both sexes, with complete maturity occurring at four years for males and five years for females. In the wild, spawning occurs in the shallow and marginal areas of flooded rivers, often during the southwest monsoon season, i.e., from April to September. In captivity, proper feeding leads to maturity by the end of the second year, but natural breeding is usually not viable in pond environments, necessitating induced breeding. The fecundity of rohu can vary significantly, ranging from 226,000 to 2,794,000 eggs depending on the fish's size and ovary weight, with an average range of 200,000-300,000 eggs per kilogram of body weight.

Mrigal is also eurythermal, tolerating a minimum temperature of 14 ºC. In culture, mrigal typically reaches 600-700 g on average stocking density and management practices in the first year. Among the three Indian major carps, mrigal tends to grow more slowly than catla and rohu. In typical rearing conditions, it's usually raised for a maximum of two years, as the growth rate diminishes with age. However, mrigal has survived for up to 12 years in natural waters. Maturity in mrigal is typically reached in two years under captivity. Since mrigal requires a riverine environment for breeding, natural breeding is unlikely to occur in ponds. Instead, induced breeding in hatcheries using hormonal induction methods has proven successful. Mrigal is highly fecund, with fecundity increasing with age. The spawning season corresponds with the onset and duration of the southwest monsoon, typically occurring from May to September in India, Bangladesh, and Pakistan, with the preferred breeding temperature range being 24-31 ºC.

Induced breeding is a widely used method for seed production in aquaculture, catering to the demand for various fish species, including catla, rohu, and mrigal. In this method, hormonal stimulation is employed to trigger controlled reproduction in these fish species, allowing for the mass production of fish fry or fingerlings. However, it's important to note that the success of induced breeding can vary between species and requires specific protocols. The induced breeding process typically involves hormonal induction using either carp pituitary extract or synthetic commercially available formulations of purified salmon gonadotropin and dopamine antagonists like Ovaprim, Ovatide, and Wova-FH. When using pituitary extract, females receive a stimulating dose of 2-3 mg/kg body weight, followed by a 2nd dose of 5 to 8 mg/kg after a 6-hour gap. Males are typically given a single dose of 2-3 mg/kg at the time of the second female injection. In the case of synthetic formulations, females are injected with a single dose of 0.4-0.5 ml/kg body weight, and males are injected with 0.2-0.3 ml/kg. The Chinese circular hatchery system is widely used for seed production, as it has proven to be efficient for large-scale production. Broodstock, typically stocked at 3-5 kg/m³, is injected with suitable inducing agents and released into a breeding tank with a water depth of about 1.5 meters. Fertilized eggs are collected 8-12 hours later and then transferred to hatching tanks for further incubation (64-72 hours). The hatched fish are typically raised through a two-tier system, involving a nursery phase lasting 15-20 days to raise fry, followed by a 2–3-month phase for fingerling production.

**4. Conclusion**

In conclusion, the Indian major carps play a pivotal role in India's aquaculture industry and have significant economic, nutritional, and cultural importance. These species have witnessed impressive growth and transformation in recent decades, expanding freshwater aquaculture production and contributing to the livelihoods of millions of people. Freshwater aquaculture, driven by technologies like induced breeding and polyculture, has become the backbone of the Indian aquaculture sector. India's abundant aquatic resources, including reservoirs, ponds, tanks, and rivers, have provided a fertile ground for the growth of these carp species. While in the mid-1980s, freshwater aquaculture represented only a portion of inland fisheries, it now dominates, constituting nearly 80% of the total production. The cultivation of the three major Indian carp species, catla, rohu, and mrigal, alongside the composite culture of exotic carp species, represents the prevailing practice. These major Indian carp species contribute significantly, making up 70 to 75% of freshwater fish production. It's important to note that each of these species has distinct ecological niches and feeding behaviours, necessitating a deep understanding for successful aquaculture and habitat management. Their reproductive strategies are central to sustainable management and knowledge of their reproductive biology, essential for both successful aquaculture and effective conservation in their natural habitat. Additionally, maintaining genetic diversity within these carp populations is vital for resilience to changing environmental conditions and disease resistance, which can be achieved through selective breeding programs. The conservation of these Indian major carps faces various challenges, such as overfishing, habitat degradation, water pollution, illegal exotic fish introduction, and the impacts of climate change. Mitigating these challenges requires a holistic approach that includes habitat restoration, sustainable fishing practices, and community engagement. This is critical to ensure the long-term sustainability of these species and the ecosystems they inhabit. Furthermore, the adoption of sustainable and eco-friendly aquaculture practices is crucial for both conservation efforts and the economic well-being of those involved in the industry. Innovations such as integrated multitrophic aquaculture (IMTA) and responsible farming practices reduce the environmental footprint and enhance the marketability of Indian major carp's products. In conclusion, the Indian major carps are not just fish; they are integral to the cultural, economic, and nutritional fabric of India. Their biology, ecology, and sustainable management are keys to preserving these species and the industry that relies on them. The chapter provides a broad overview of these important carp species, emphasizing their significance and the strategies needed to ensure their continued presence in India's aquatic ecosystems. By combining scientific knowledge with responsible practices, India can secure the future of these remarkable fish and the livelihoods they support.

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