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

**Gyan Chandra, Rupam Samanta, Anjali Pushp**

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, the introduction of non-native species, 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 carps (silver carp, grass 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 to ensure the long-term sustainability of these 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, is a species of 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. Its higher growth rate and compatibility with other major carps, specific surface feeding habits, and consumer preference have increased its popularity in carp polyculture systems among the fish farmers in India, Bangladesh, Myanmar, Laos, Pakistan and Thailand. The species has also been introduced elsewhere, including Sri Lanka, Israel, Japan, and Mauritius. At present, catla forms 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 features

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

|  |  |
| --- | --- |
| 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 among the three Indian major carps used in carp polyculture systems. This graceful Indo-Gangetic riverine species is the natural inhabitant of the riverine system of northern and central India and the rivers of Pakistan, Bangladesh and Myanmar. In India, it has been transplanted into almost all riverine systems, including the freshwaters of Andaman, where its population has been successfully established. The species has also been introduced in many other countries, including Sri Lanka, the former USSR, Japan, China, the Philippines, Malaysia, Nepal and some countries of Africa. Its high growth potential, coupled with high consumer preference, has established rohu as the most important freshwater species cultured in India, Bangladesh and other adjacent countries in the region. Considering its importance in the culture system, emphasis has also been given to its genetic improvement through selective breeding in India.

Identifying biological features

Body bilaterally symmetrical, moderately elongate, its dorsal profile more arched than the ventral profile; body with cycloid scales, head without scale; snout fairly depressed, projecting beyond mouth, without lateral lobe; eyes dorsolateral in position, not visible from outside of head; mouth small and inferior; lips thick and fringed with a distinct inner fold to each lip, lobate or entire; a pair of small maxillary barbels concealed in lateral groove; no teeth on jaws; pharyngeal teeth in three rows; upper jaw not extending to front edge of eye; simple (unbranched) dorsal fin rays three or four, branched dorsal fin rays 12 to 14; dorsal fin inserted midway between snout tip and base of caudal fin; pectoral and pelvic fins laterally inserted; pectoral fin devoid of an osseous spine; caudal fin deeply forked; lower lip usually joined to isthmus by a narrow or broad bridge; pre-dorsal scale 12-16; lateral line distinct, complete and running along median line of the caudal peduncle; lateral line scales 40 to 44; lateral transverse scale-rows six or six and a half between lateral line and pelvic fin base; snout not truncate, without any lateral lobe; colour bluish on back, silvery on 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 Mrigala, is a freshwater fish belonging to the family Cyprinidae. Mrigal (*Cirrhinus mrigala*), a carp endemic to Indo-Gangetic riverine systems, is one of the three Indian major carps cultivated widely in Southeast Asian countries. This species 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 features

Body bilaterally symmetrical and streamlined, its depth about equal to the length of head; body with cycloid scales, head without scales; snout blunt, often with pores; mouth broad, transverse; upper lip entire and not continuous with the lower lip, lower lip most indistinct; single pair of short rostral barbels; pharyngeal teeth in three rows, 5.4.2/2.4.5 pattern; lower jaw with a small post-symphysial knob or tubercle; origin of dorsal fin nearer to end of snout than the base of caudal; dorsal fin as high as the body with 12 or 13 branched rays; last unbranched ray of dorsal fin non-osseous and non-serrated; pectoral fins shorter than head; caudal fin deeply forked; anal fin not extending to caudal fin; lateral line with 40-45 scales; lateral transverse scale rows 6-7/5½-6 between lateral line and pelvic fin base; usually dark grey above, silvery beneath; dorsal fin greyish; 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. The time it takes for Indian major carps to reach maturity can vary depending on various factors, including water temperature, food availability, and overall environmental conditions. At this stage, they have fully developed reproductive organs and can participate in the reproduction cycle.

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 to 1-1.2 kg in the first year, compared to 700-800 g for Rohu 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 coinciding with the southwest monsoon season 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 in the first year, depending on stocking density and management practices. 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 been known to survive 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 commercial 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 second 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 receive a single dose of 0.4-0.5 ml/kg body weight, and males receive 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, the introduction of non-native species, 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 environmentally 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. This chapter provides a comprehensive 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.

**References**

1. Ayyappan, S., & Jena, J. N. (2001). Sustainable freshwater aquaculture in India. In T. J. Pandian (Ed.), Sustainable Indian Fisheries (pp. 83-133). National Academy of Agricultural Sciences, New Delhi, India.
2. Jena, J. K., Aravindakshan, P. K., Chandra, S., Muduli, H. K., & Ayyappan, S. (1998a). Comparative evaluation of growth and survival of Indian major carps and exotic carps in raising fingerlings. Journal of Aquaculture in the Tropics, 13, 143-150.
3. Jena, J. K., Aravindakshan, P. K., & Singh, W. J. (1998b). Nursery rearing of Indian major carps fry under different stocking densities. Indian Journal of Fisheries, 45(2), 163-168.
4. Jhingran, V. G. (1968). Synopsis of Biological Data on Rohu, *Cirrhinus mrigala* (Hamilton, 1822). FAO Fisheries Synopsis No. 32, FAO, Rome, Italy.
5. Jhingran, V. G. (1991). Fish and Fisheries of India. Hindustan Publishing Corporation (India), Delhi, India. 727 pp.
6. Khoke, U. C. (1995). Shrimp and carp aquaculture and the environment. Myanmar Study Report. In Regional Study and Workshop on Aquaculture sustainability and the environment. Manila, Asian Development Bank & Bangkok, Network of Aquaculture Centres in Asia-Pacific. [Draft report]
7. Pathak, S. C., & Palanisamy, K. (1995). Shrimp and carp aquaculture and the environment. India Study Report. In Regional Study and Workshop on Aquaculture sustainability and the environment. Manila, Asian Development Bank & Bangkok, Network of Aquaculture Centres in Asia-Pacific. [Draft report]
8. Singh, D. M. (1995). Shrimp and carp aquaculture and the environment. Nepal Study Report. In Regional Study and Workshop on Aquaculture sustainability and the environment. Manila, Asian Development Bank & Bangkok, Network of Aquaculture Centres in Asia-Pacific. [Draft report]
9. Somalingam, J., Maheshwari, U. K., & Langer, R. K. (1990). Mass production of intergeneric hybrid catla (*Catla catla* x *Labeo rohita*) and its growth in ponds, small and large reservoirs of Madhya Pradesh. In P. Keshavanath & K. V. Radhakrishnan (Eds.), Proceedings of the workshop on carp seed production technology (pp. 49-52). Asian Fishery Society Indian Branch, Mangalore, India.
10. Talwar, P. K., & Jhingran, A. G. (1991). Inland Fishes of India and Adjacent Countries. Volume 1. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, India. 541 pp.
11. FAO. (2016). Fishery and aquaculture statistics 2014. Food and Agricultural Organization, Rome, 204 pp.
12. Ayyappan, S., & Jena, J. K. (2003). Grow-out production of carps in India. Journal of Applied Aquaculture, 13, 251-282.
13. FAO. (2017). National aquaculture overview: India. Country profile fact sheets. FAO Fisheries and Aquaculture Department, FAO, Rome. <http://www.fao.org/fishery/factsheets/en> (Accessed 1 December 2017).
14. CIFA. (2004). CIFA technologies. Central Institute of Freshwater Aquaculture, Bhubaneswar, Odisha, India.
15. Jayasankar, P. (2018). Present status of freshwater aquaculture in India: A review. Indian Journal of Fisheries, 65(4), 157-165.
16. Chandra, G., & Fopp-Bayat, D. (2021). Trends in aquaculture and conservation of sturgeons: A review of molecular and cytogenetic tools. Reviews in Aquaculture, 13, 119-137.
17. Chandra, G., & Saxena, A. (2013). Morphometric characteristics and conservation of the vulnerable fish, *Eutropiichthys vacha* (Hamilton, 1822) in the rivers of Ganga and Kosi, North India. Journal of Experimental Zoology, India, 16(1), 97-99.
18. Chandra, G., & Saxena, A. (2014). Fisheries and Management Status of Gogabeel Lake, Katihar, Bihar. Ecology, Environment and Conservation. Supplement Issue: 123-126.
19. Chandra, G., Saxena, A., & Barat, A. (2010). Genetic diversity of two riverine populations of *Eutropiichthys vacha* (Hamilton, 1822) using RAPD markers and implications for its conservation. Journal of Cell Molecular Biology, 8(2), 77-85.
20. Chandra, G., Chaudhary, P. K., & Kumar, M. (Year not provided). Integrated fish farming system: A way towards sustainability and prosperity of farmers.
21. Chandra, G., Misra, V. K., & Singh, S. (2020). Fish Faunistic Diversity in Kosi River at Supaul, Bihar. Journal of Krishi Vigyan, 9(si), 106-109.
22. Basavaraju, Y., & Varghese, T. J. (1980). A comparative study of growth rate of rohu - mrigal and mrigal - rohu hybrids and their parental species. Mysore Journal of Agricultural Sciences, 14(3), 388-395.
23. Choudhury, S. N. (1995). Shrimp and carp aquaculture and the environment. In Bangladesh Study Report. Regional Study and Workshop on Aquaculture Sustainability and the Environment. Manila, Asian Development Bank & Bangkok, Network of Aquaculture Centres in Asia-Pacific. [Draft report]
24. CIFA. (2004). Annual Report Central Institute of Freshwater Aquaculture. Bhubaneswar. CIFA, 99 pp.
25. Gopakumar, K., Ayyappan, S., Jena, J. K., Sahoo, S. K., Sarkar, S. K., Satapathy, B. B., & Nayak, P. K. (1999). National Freshwater Aquaculture Development Plan. CIFA, Bhubaneswar, India, 75 pp.
26. Gupta, S. D., Rath, S. C., Dasgupta, S. D., & Tripathi, S. D. (1995). A first report on quadruple spawning of *Catla catla* (Ham.). Veterinarski Arhiv, 65(5), 143-148.
27. Hayat, M. (1995). Shrimp and carp aquaculture and the environment. Pakistan Study Report. In Regional Study and Workshop on Aquaculture Sustainability and the Environment. Manila, Asian Development Bank, and Bangkok, Network of Aquaculture Centres in Asia-Pacific. [Draft report]
28. Jayaram, K. C. (1981). The Freshwater Fishes of India, Pakistan, Bangladesh, Burma, and Sri Lanka. Handbook of Zoological Survey of India, Volume 2. Calcutta, India. 475 pp.