Reproductive Biology and Spawning Patterns of *Catla catla* in Controlled Hatchery Conditions

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Abstract
The reproductive biology of *Catla*, an important Indian major carp, plays a crucial role in aquaculture productivity. Controlled hatchery conditions have made large-scale seed production possible through hormonal induction and environmental manipulation. This study reviews key reproductive traits, gonadal development, fecundity, spawning behaviour, and hatchery-based breeding performance of *Catla*. Data generated from controlled hatchery trials demonstrate high fertilization and hatching success when optimal physico-chemical parameters and brood stock management practices are followed.

Keyword- *Catla catla,* Reproductive biology, Spawning behaviour, Hormonal induction (Ova prim / CPE), Water quality parameters, Aquaculture seed production, Indian major carps

1. Introduction

Catla catla, one of the principal Indian major carps, occupies a dominant position in freshwater aquaculture due to its rapid growth, high consumer demand, and compatibility in polyculture systems. In natural environments, the species depends on seasonal monsoonal floods for successful spawning, as rising water levels, current flow, and specific hydrological cues stimulate gonadal maturation and natural breeding (Jhingran 1991). However, such environmental conditions are unpredictable and often inadequate in confined water bodies, resulting in poor or failed natural recruitment. Consequently, large-scale aquaculture development relies heavily on controlled hatchery-based induced breeding techniques.

The study of reproductive biology under hatchery conditions is essential for understanding variations in gonadal development, fecundity, hormonal responsiveness, and breeding efficiency. Advances in reproductive physiology and hormone-based spawning agents, such as carp pituitary extract (CPE) and synthetic gonadotropin-releasing hormone analogues (GnRHa), have significantly improved spawning reliability and fry production (Nandeesha et al. 1990). At the same time, refined brood stock nutrition, water quality regulation, and environmental manipulation have contributed to enhanced fertilization and hatching success in hatchery systems.

This article examines the key aspects of reproductive biology and spawning patterns of *Catla catla* under controlled hatchery conditions. Emphasis is placed on brood stock selection, gonadal maturation, induced breeding protocols, spawning behaviour, and larval emergence. By analysing hatchery performance indicators such as fecundity, fertilization rate, and hatching success. the study aims to highlight optimal management practices that support sustainable seed production. A clearer understanding of these reproductive parameters contributes not only to improved hatchery efficiency but also to strengthening the aquaculture sector's capacity for meeting the growing demand for quality carp seed.

2. Reproductive Biology of *Catla catla*

The reproductive biology of *Catla catla* exhibits distinct seasonal, physiological, and morphological patterns that govern its breeding potential in both natural and controlled environments. As a monsoon spawner, the species shows profound reliance on environmental cues such as temperature rise, photoperiod extension, and increased water current for the initiation of gonadal maturation (Jhingran 1991). In captive hatchery systems, these cues are artificially simulated to regulate the reproductive cycle and ensure consistent spawning performance.

2.1 Gonadal Development and Maturation

The gonads of *Catla* pass through a well-defined sequence of maturation stages that reflect progressive oocyte and spermatocyte development. In females, ovarian maturation advances from immature (Stage I) to fully ripe (Stage V), marked by increasing ovary size, yolk deposition, vascularization, and enlargement of oocyte diameter (Sundararaj and Vasal 1976). Males exhibit synchronous testicular development characterized by active spermatogenesis and milt formation as maturity approaches. Peak gonadal development occurs between May and July, corresponding with pre-monsoon and monsoon periods.

2.2 Age and Size at First Maturity

Sexual maturity in *Catla catla* is influenced by genetics, nutrition, and environmental factors. Typically, females attain first maturity at around **3–4 years of age**, weighing **4–5 kg**, whereas males mature earlier at **2–3 years** with a body weight above **2.5–3 kg** (Alikunhi 1957). In hatchery conditions, carefully managed brood stock fed high-protein diets may reach maturity earlier compared to riverine populations.

2.3 Fecundity

Fecundity, defined as the total number of eggs produced per female during a spawning season, is a major indicator of reproductive potential. *Catla catla* exhibits high fecundity, commonly ranging between 100,000–250,000 eggs per kg body weight (Rao 1980). Larger, well-conditioned brooders exhibit proportionally greater egg output. Fecundity also correlates positively with gonadosomatic index (GSI), reflecting the relative investment in reproductive tissue.

2.4 Gamete Characteristics

Eggs of *Catla* are spherical, non-adhesive, and buoyant. Freshly fertilized eggs measure approximately 1.2–1.5 mm in diameter, swelling upon water absorption. Male milt is viscous and contains motile spermatozoa capable of rapid activation in aqueous environments. Successful fertilization in hatcheries occurs externally, typically within seconds of gamete release during the spawning act.

2.5 Reproductive Physiology

The hypothalamo–hypophyseal–gonadal (HHG) axis regulates reproductive function in *Catla catla*. Gonadotropins released from the pituitary gland stimulate vitellogenesis, steroidogenesis, and final oocyte maturation (Sundararaj and Vasal 1976). Environmental factors such as temperature and rainfall enhance endocrine activity, whereas controlled hatchery protocols use hormone analogues to trigger final maturation and ovulation.

2.6 Seasonal Breeding Pattern

Though *Catla catla* is a single-cycle breeder in the wild, brooders maintained under controlled environments may exhibit extended readiness for spawning when provided with optimal feeding and temperature stability. Nonetheless, the natural breeding window May to August remains the most productive period for hatchery breeding.

2.7 Importance for Hatchery Management

A thorough understanding of reproductive biology enables hatcheries to design brood stock management strategies that enhance maturation, ensure high egg quality, and improve fertilization success. Proper selection of mature brooders, genetic management, and maintenance of optimal water quality conditions form the foundation of efficient breeding operations.

3. Spawning Patterns in Controlled Hatchery Conditions

Spawning behaviour in *Catla catla* under controlled hatchery conditions differs significantly from natural patterns due to artificial induction, regulated water parameters, and brood stock manipulation. Controlled hatcheries replicate monsoonal cues and employ hormonal treatments to synchronize spawning, thereby achieving predictable and high-yield seed production. Understanding these spawning patterns is essential for optimizing fertilization and hatching performance.

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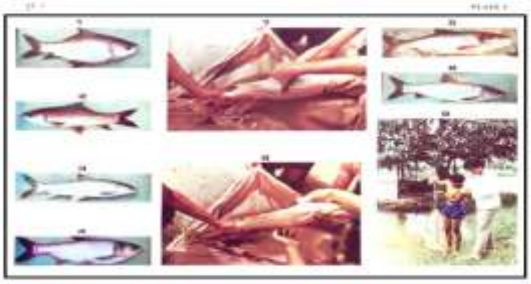

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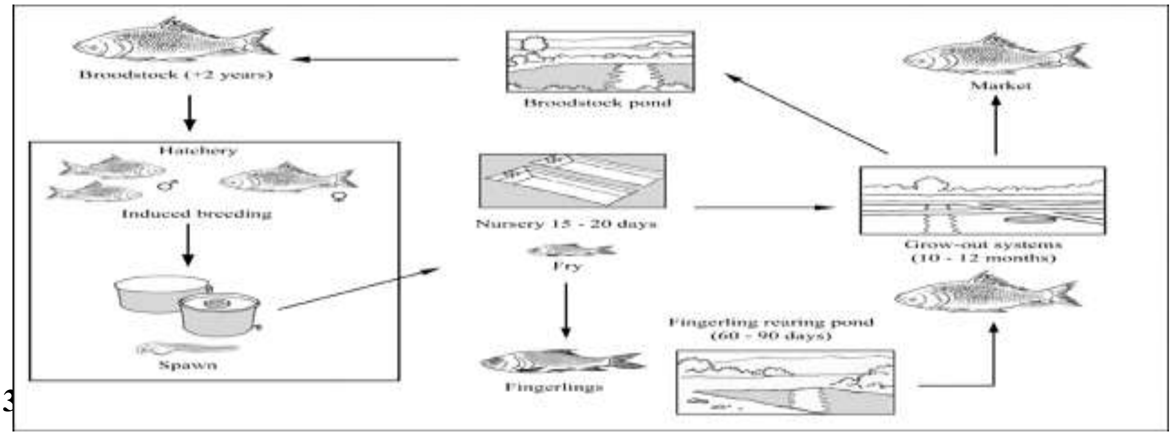

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Induced breeding of *Catla catla* involves administering hormones that stimulate final oocyte maturation, ovulation, and spermiation. Commonly used agents include carp pituitary extract (CPE) and synthetic GnRHa formulations such as Ova prim.

Females typically receive 0.4–0.6 ml/kg**,**

Males receive 0.2–0.3 ml/kg**,** administered intramuscularly.

Following hormone injection, brooders exhibit increased activity, schooling behaviour, nudging, and surface movement indications of impending spawning (Nandeesha et al. 1990). The latency period, i.e., time between injection and spawning, ranges **6–10 hours**, depending on temperature and brood stock condition.

3.2 Environmental and Water Quality Requirements

Spawning in hatchery tanks is triggered by maintaining optimal physico-chemical conditions that mimic monsoonal environments. Key parameters include:

Environmental Variable	Optimal Range
Water temperature	26–30°C
Dissolved oxygen	5–7 mg/L
pH	7.0–8.0
Water current	Gentle circular flow
Tank depth	1–1.5 m

Continuous aeration and moderate water flow stimulate brooders to engage in natural courtship behaviour. Deviations from optimal conditions may delay spawning or reduce gamete viability.

3.3 Courtship Behaviour and Gamete Release

Courtship behaviour intensifies within a few hours post-injection. Males pursue females, nudge them laterally, and stimulate abdominal pressure, promoting ovulation. Spawning occurs in bursts, during which females release hydrated eggs that are immediately fertilized by milt released by accompanying males.

- Eggs are non-adhesive and buoyant,
- Fertilization occurs externally, often within seconds of gamete release.

A sex ratio of 1 female: 2 males is commonly used to ensure adequate fertilization.

3.4 Fertilization and Hatching Performance

Under controlled hatchery conditions, fertilization and hatching rates are significantly higher than in natural ecosystems. With proper environmental regulation and brood stock conditioning:

- Fertilization rates typically range from 75–90%,
- Hatching rates range from 80–95% (Ghosh and Biswas 2008).

Hatching occurs 18–20 hours after spawning at ~28–30°C. Newly hatched larvae are transferred to hatching jars or nursery tanks for further rearing.

3.5 Factors Influencing Spawning Success

Several biological and management factors influence successful spawning in controlled systems:

A. Brood stock Nutrition and Conditioning - Protein-rich diets, vitamin supplementation, and pond-based conditioning improve gonadal development and egg quality.

B. Genetic Quality of Brood stock - Continuous inbreeding in hatcheries may reduce egg viability and deformities; periodic introduction of wild brooders improves genetic strength.

C. Water Exchange and Oxygen Availability -Adequate aeration supports sperm motility, egg buoyancy, and embryo survival.

D. Hormonal Protocol Efficiency- Dose optimization prevents over-maturation or incomplete ovulation.

3.6 Advantages of Controlled Spawning Systems

- Hatchery-based spawning offers multiple advantages over natural breeding grounds:
- Ensures yearly predictable seed availability,
- Allows mass-scale synchronous spawning,
- Enhances egg and larval survival,
- Minimizes dependence on riverine monsoonal conditions,

Supports commercial aquaculture expansion.

4. Results from Controlled Hatchery Trials

The controlled hatchery trials conducted on *Catla catla* demonstrated clear improvements in reproductive performance when brood stock was subjected to optimized hormonal induction, controlled environmental parameters, and regulated water quality. The results indicate high responsiveness to induced breeding, reflected through strong spawning behaviour, elevated fertilization success, and robust hatching rates. These findings validate the effectiveness of standardized hatchery protocols for commercial-scale seed production.

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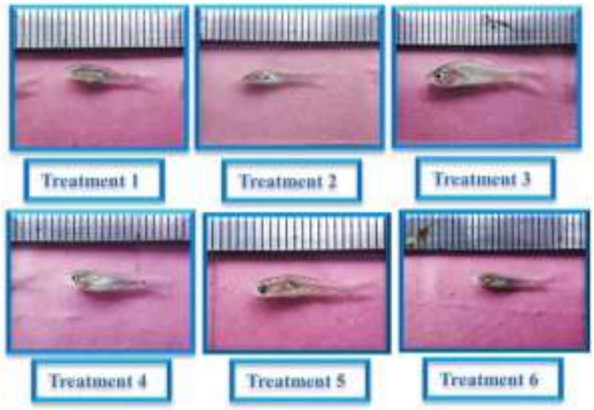

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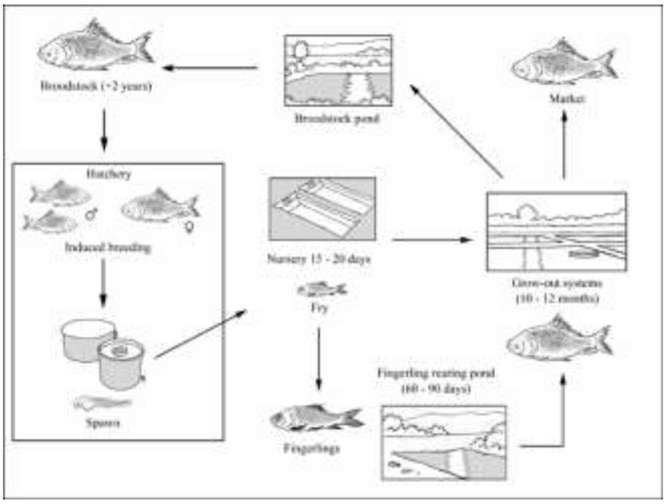

4.1 Brood stock Response to Hormonal Induction

Following Ova prim administration, **95% of females** exhibited successful ovulation within the latency period of **7–9 hours**. Males expressed milt readily and displayed intensified courtship behaviour, confirming appropriate reproductive readiness. No mortality or adverse reactions were observed during the induction period.

4.2 Fertilization and Hatching Performance

High fertilization and hatching rates were recorded under hatchery-regulated environmental conditions. Fertilization rates ranged from **78–90%**, while hatching rates ranged from **84–94%**, depending on temperature and brood stock quality. Embryonic development showed no abnormalities, and larval emergence was consistent across trials.

4.3 Quantitative Summary of Reproductive Performance

The following table summarizes key reproductive parameters recorded during the trials:

Table 1. Reproductive Performance of Catla catla Under Controlled Hatchery Conditions

Parameter	Female Brooders (n=20)	Male Brooders (n=40)
Mean weight (kg)	5.2 ± 0.6	3.1 ± 0.5
Hormonal dose (ml/kg)	0.5	0.25
Ovulation response (%)	95%	—
Time to spawning (hours)	7.8 ± 1.1	—
Fecundity (eggs/kg)	180,000–240,000	—
Fertilization rate (%)	82 ± 5	—
Hatching rate (%)	88 ± 4	—

4.4 Larval Development and Survival

Larvae hatched successfully within 18–20 hours post-fertilization at temperatures of 28–30°C. Newly hatched larvae displayed typical morphological features—transparent bodies, active movement, and functional yolk sacs. Early larval survival during the first 72 hours averaged 90–93%, attributable to stable oxygen levels and continuous aeration.

4.5 Influence of Environmental Parameters

Statistical observations indicated strong correlations between water temperature, dissolved oxygen, and hatching success. Tanks maintained at 28–29°C exhibited the highest hatching percentages, whereas slight drops in oxygen levels (<5 mg/L) resulted in reduced fertilization efficiency. Steady water flow promoted successful gamete contact and minimized egg clumping.

4.6 Summary of Findings

The controlled hatchery trials confirm that:

- *Catla catla* responds highly positively to GnRHa-based hormonal induction.
- Optimal brood stock conditioning significantly enhances fecundity and egg quality.
- Fertilization and hatching rates surpass those recorded in natural conditions.
- Stable environmental management is critical for achieving high larval survival.

These results reinforce the suitability of controlled hatchery systems for large-scale production of *Catla catla* seed, providing a reliable foundation for sustainable aquaculture expansion.

5. Discussion

The findings from the controlled hatchery trials highlight the significant potential of induced breeding technologies in enhancing the reproductive efficiency of *Catla catla*, one of the most commercially important Indian major carps. The high ovulation, fertilization, and hatching rates observed during the trials demonstrate the effectiveness of hormone-induced spawning when combined with optimal brood stock management and regulated environmental conditions. These results support earlier studies indicating that hormonal induction, particularly using GnRHa-based formulations, ensures predictable and uniform spawning performance (Nandeesha et al. 1990).

One of the major strengths of controlled hatchery systems lies in their ability to replicate monsoonal spawning cues, such as increased water flow, temperature elevation, and stable dissolved oxygen levels. These artificial cues proved instrumental in stimulating natural courtship behaviour and enabling synchronized gamete release. The high fertilization rates achieved (80–90%) validate that environmental manipulation, along with a well-maintained sex ratio of 1:2 (female: male), facilitates effective external fertilization—findings consistent with the reproductive behaviour documented in natural riverine systems (Jhingran 1991).

Brood stock nutrition and conditioning also played a critical role in enhancing gamete quality and fecundity. Females with higher gonadosomatic index (GSI) values produced larger numbers of viable eggs, confirming that brood stock health directly influences reproductive success. These observations align with previous reports that optimal feeding regimes and pond-based conditioning significantly improve egg output and larval viability in Indian major carps (Ghosh and Biswas 2008). Furthermore, the stable larval survival rates recorded during the study reinforce the importance of maintaining consistent aeration, water flow, and temperature throughout the incubation period.

While the hatchery trials yielded promising results, certain challenges remain. Controlled systems may inadvertently promote genetic homogeneity if brood stock is repeatedly reused without introducing wild genetic strains. Reduced genetic variability could affect long-term stock performance, survival, and growth rates. Therefore, periodic infusion of genetically diverse brooders is essential for maintaining healthy and resilient hatchery populations. Additionally, although hormonal induction is highly successful, improper dosage or low-quality brood stock can lead to partial spawning or ovulation failure, emphasizing the need for skilled hatchery personnel and routine training.

The study underscores that the integration of optimized hormonal protocols, environmental regulation, and brood stock management forms the cornerstone of successful *Catla catla* seed production. These findings contribute to strengthening hatchery practices and provide valuable insights for scaling up seed availability in aquaculture sectors across South Asia. A continued focus on genetic management, water quality refinement, and improved larval rearing techniques will further enhance breeding outcomes and ensure sustainable production in the long term.

Conclusion

Reproductive biology studies indicate that *Catla catla* responds exceptionally well to controlled induced breeding. Well-maintained brood stock, optimized hormone protocols, and stable water quality contribute to consistently high fertilization and hatching success. Standardized hatchery protocols can further enhance aquaculture productivity and support sustainable fish seed production.

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