Innovative Approaches in Aquaculture Research (VOLUME-1)

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About the Book

This book is a comprehensive compilation of recent research and field-based studies in the domain of freshwater aquaculture and fish reproductive biology, with special emphasis on innovative breeding techniques, sustainable fish farming models, and conservation of indigenous fish biodiversity. It brings together a series of practical investigations and scientific analyses conducted in the central Indian region, particularly around Bhopal, Madhya Pradesh.

The chapters in this volume cover key aspects such as:

- Induced breeding of commercially and nutritionally important fishes including ornamental species like *Oranda Goldfish*, and indigenous species like *Clarias batrachus* and *Heteropneustes fossilis* using hormonal agents such as Ovafish, Ovatide, and Gonopro-FH.
- Practical demonstrations of mini portable hatchery systems, offering scalable and low-cost solutions for rural fish seed production.
- Polyculture systems integrating Small Indigenous Fish Species (SIFS) with Indian Major Carps, aimed at enhancing pond productivity and promoting dietary diversity in rural households.
- Experimental studies on the effect of environmental manipulations like greenlight exposure on the growth of Indian Major Carps, introducing low-cost innovations for increasing yield.
- Morphological and reproductive studies of small indigenous fishes and catfish species, essential for understanding reproductive cycles, gonadal maturation, and species conservation.
- Wetland and riverine ecosystem assessments around Bhopal, documenting current biodiversity status, ecological threats, and conservation priorities.

The book is designed to serve a wide readership including fisheries students, hatchery technicians, extension officers, policy planners, and small-scale farmers. It not only contributes to the academic understanding of fish breeding and ecosystem dynamics but also provides practical insights into field-level technologies and strategies for sustainable aquaculture and biodiversity conservation.

By linking laboratory research to on-ground implementation, this book represents a significant step toward technology transfer and livelihood enhancement in the fisheries sector, especially for the rural communities engaged in aquaculture.

Preface

The present volume is a compendium of scientific research and practical advancements in the field of aquaculture, with a special focus on induced breeding, reproductive biology, sustainable polyculture systems, and aquatic biodiversity conservation. With the growing demand for fish protein and the urgent need for biodiversity preservation, this book aims to bridge the gap between research innovation and grassroots implementation, especially in the context of small-scale and rural aquaculture practices.

This book begins with a series of studies on induced breeding techniques involving economically and ecologically significant fish species such as *Oranda Goldfish (Carassius auratus)*, *Clarias batrachus*, and *Heteropneustes fossilis*. These chapters provide valuable insights into the application of hormonal agents like Ovafish, Ovatide, and Gonopro-FH in both conventional and mini portable hatchery systems, demonstrating scalable models for fish seed production. Particular emphasis has been laid on embryonic development and hatchery management techniques tailored for field-level extension and farmer adoption.

The volume also delves into innovative polyculture practices, specifically integrating small indigenous fish species **(*Systomus sarana, Pethia ticto, Rasbora daniconius*)** with Indian Major Carps. These species hold potential not only for enhancing biodiversity in aquaculture ponds but also for addressing nutritional security in rural communities through micronutrient-rich fish production. Further chapters explore the influence of environmental factors, such as the application of greenlight for growth enhancement in carp culture. This emerging area of research opens new directions in light-based aquaculture technology for boosting productivity.

Adding to the biological understanding, the book features a morphological and reproductive analysis of gonadal structures in small indigenous fishes and indigenous catfish species, contributing significantly to species identification, brood stock management, and conservation breeding programs.

Lastly, this book underscores the ecological context by assessing the current status of wetlands and riverine biodiversity in and around Bhopal district, Madhya Pradesh. These findings provide a vital reference for environmental monitoring, aquatic resource management, and community-based conservation efforts.

This compilation is the result of collaborative efforts by researchers, students, and extension professionals. It is intended for use by students, researchers, policymakers, and fish farmers alike, offering both scientific rigor and practical relevance. We hope this volume serves as a valuable resource to strengthen sustainable aquaculture and biodiversity conservation in India and beyond.

CONTENT

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Induced breeding of oranda goldfish (*Carassius auratus*) by using ovafish

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Abstract

The present study investigated the induced breeding of Oranda goldfish (*Carassius auratus*) using Ovafish hormone under controlled conditions at the Meghalaya State Fisheries Research and Training Institute (MSFRTI), Mawpun, Meghalaya, from July to December 2023. Brooders were conditioned for 25 days in disinfected and pre-prepared tanks, and fed a high-protein diet comprising bloodworms and TetraBits. Physico-chemical parameters of both brood and breeding tanks were closely monitored, maintaining optimal ranges for temperature (28–31°C in brood tanks; 20–26°C in breeding tanks), dissolved oxygen (5–6 ppm), pH (7.3–7.6), alkalinity (140–200 mg/L), and hardness (100–120 mg/L). Hormonal induction was carried out using Ovafish at dosages of 0.5 ml/kg for females and 0.2 ml/kg for males. The treatment resulted in a significantly higher fertilization and hatching success rate (~93%) compared to natural breeding (~65%). Fertilized eggs were identified by their transparent shells with grey or black spots, while unfertilized eggs appeared opaque. The study concludes that Ovafish is effective in enhancing reproductive success in *C. auratus*, suggesting its potential application in ornamental fish hatcheries to improve breeding efficiency.

Keywords: Induced breeding, Ovafish hormone, Carassius auratus.

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1 Introduction

Aquaculture is the farming of aquatic organisms such as fish, crustaceans, molluscs, and aquatic plants. It involves the controlled cultivation of both plants and animals in water environments. According to the FAO (1990), aquaculture implies some degree of human intervention in the rearing process to enhance production. This may include practices such as regular stocking, feeding, and protection from predators. The scope of aquaculture encompasses husbandry, management, nutrition, breeding, and multiplication of useful aquatic species. Much like how traditional farming replaced hunting and gathering, aquaculture is progressively replacing the wild capture of aquatic animals, helping meet the growing demand for aquatic products.

India is a global leader in aquaculture, ranking as the third-largest fish-producing country and the second-largest in aquaculture fish production, contributing approximately 7% to global fish production. Among the various aquaculture practices, catfish farming is considered one of the highest-yielding activities within the primary production sector, with global average yields ranging from 250 to 400 tonnes per hectare per crop (Ayyappan et al., 2006).

The technique of induced breeding was first developed in Argentina, where pituitary extracts were used to stimulate ovulation in fish. Houssay (1931) was among the pioneers who observed that viviparous fishes injected with fresh fish pituitary extracts gave birth prematurely. This technique was further refined in Brazil by 1934, and by the mid-20th century, it had been adopted widely in the United States, Russia, and other countries. Notable contributions include those of Houssay (1931), Iherring (1937), Fontenele (1955), and Gerbilsky (1938). Induced breeding is a reliable method for artificial propagation and mass production of fish seed, especially during the off-breeding season. The technique involves the administration of pituitary gland extracts or synthetic hormones to ripening fish in confined water conditions, triggering spawning. Unlike natural spawning, which depends heavily on monsoon conditions and is unpredictable, induced breeding ensures a steady supply of fish seed, thus supporting consistent aquaculture production.

In recent years, the keeping of ornamental fish has become a popular global hobby. Millions of enthusiasts around the world enjoy watching these vibrant creatures in aquariums, which also enhances the aesthetic appeal of homes. The global ornamental fish trade is valued at approximately $9 billion, with freshwater species making up 85% of the trade and marine species accounting for the rest. The sector is one of the fastest-growing in fisheries, witnessing an annual growth rate of over 10% globally and around 20% domestically.

There are around 300 varieties of freshwater ornamental fish available in the market, each with unique trade names and appeal. Among them, the goldfish (*Carassius auratus*) stands out as the most popular and widely kept species. Belonging to the family Cyprinidae and the order Cypriniformes, goldfish are known for their wide range of colors, body shapes, fin types, and sizes.

Although they resemble carp (*Cyprinus carpio*), goldfish can be distinguished by their lack of barbels and the absence of dark spots at the base of their scales. They are omnivorous, feeding on both live and

prepared foods, and can swim at all water levels in a tank. They accept both floating and sinking feeds, making them easy to care for. Goldfish can generally live for 10–12 years, with some even reaching 43 years in captivity. They are typically divided into two categories: fancy and common. Fancy goldfish grow up to 6–8 inches, while common goldfish can reach lengths of up to 14 inches. Their peaceful nature and compatibility make them ideal for community aquariums.

A. Methods and Materials

The present study was conducted between July and December 2023 at the Meghalaya State Fisheries Research and Training Institute (MSFRTI), located in Mawpun, Meghalaya. Brooders used for the experiment were collected from the Institute's pond using scoop nets and small hand nets. To ensure the health of the brooders and to minimize stress or potential infections, they were treated with a mild potassium permanganate ($KMnO_4$) solution for 3–4 minutes. Following this treatment, the brooders were transferred to pre-prepared tanks for broodstock management.

Before the introduction of the brooders, the breeding tanks were thoroughly cleaned. The tanks were first washed with clean water, followed by disinfection using $KMnO_4$, and finally rinsed again with water to eliminate any residues. This cleaning process was essential to prevent the presence of germs or harmful bacteria that could affect the health and breeding performance of the broodstock. The broodstock management phase lasted for 25 days during the breeding season, specifically from September to October 2023. During this period, special attention was given to the diet and overall health of the brooders. They were fed a high-protein diet that included nutritious bloodworms and TetraBits, ensuring a balanced and supplementary nutritional intake to support reproductive development.

Throughout the experimental period, both the brooders' tank water and hatchery water were monitored for various physical and chemical parameters. These included flow rate, temperature, pH, dissolved oxygen (DO), free carbon dioxide (CO_2), total hardness, alkalinity, nitrate, nitrite, total ammonia, phosphate, iron, and calcium. The analyses were conducted following the standard procedures outlined by the American Public Health Association (APHA, 2005).

B. Aquarium preparation

Two aquariums were prepared before, that is brood tank and the breeding tank.

1. Brood tank

Two separate tanks of the same measurement (40x30x30cm) were prepared for stocking both the male and female brooders. Separately, both tanks were sterilized by cleaning them with $KMnO_4$ for the removal of any infections and bacteria. After cleaning, the brooders were released separately to attain better results for the breeding.

2. Breeding tank

A relatively big tank with measurements 90x45x45cm was prepared to allow proper movement of the brooders inside the tank. Since the eggs of *C. auratus* are adhesive in nature, locally available grass was

added to the tank for the eggs to stick. Both the male and female brooders were released after being injected with hormones that allow them to reproduce.

3. Hormones Preparation

Brooders were injected using the syringe injection made with 0.5 mm ovafish hormone and 9.5 mm distilled water in a 1 ml syringe, depending on the length and weight of the fish.

2 Results and Discussion

A. Physio-chemical parameters

1. Temperature

In the present study, Oranda goldfish were observed to breed within specific temperature ranges. During the brood stock management phase, the temperature of the brood tanks ranged between 28–31°C, while in the breeding tanks, the temperature was maintained between 20–26°C. These ranges supported optimal physiological conditions for maturation and spawning.

2. DO

In this study, the dissolved oxygen concentration was approximately 5 ppm in the brood tanks and ranged between 5–6 ppm in the breeding tanks, ensuring sufficient oxygen for both brooders and eggs.

3. pH

The pH of the brood tanks was maintained between 7.3–7.4, while the breeding tanks had a slightly higher pH range of 7.5–7.6, which is considered ideal for spawning.

4. Alkalinity

Alkalinity serves as a buffer against rapid pH fluctuations and contributes to overall water stability. During the study, the total alkalinity of the brood tanks ranged from 140 to 170 mg/L, while in the breeding tanks, it was slightly broader, ranging from 140 to 200 mg/L.

5. Total Hardness

Water hardness is another important factor that affects the physiology and reproduction of fish. In both the brood tanks and breeding tanks, the total hardness was consistently maintained between 100–120 mg/L, providing a stable environment conducive to successful breeding and egg development.

The range of physico-chemical parameters of the brood tank during the broodstock management is presented in Table 1

Table 1 Physico-chemical Parameters of Brood Tank during broodstock management

Water Temperature (°C)	**20-31 °C**
Dissolved Oxygen (DO)	**5-6ppm**
Water pH	**7.3-7.6**

Total Alkalinity(mg/l)	**140-200 mg/l**
Total Hardness (mg/l)	**100-120 mg/l**

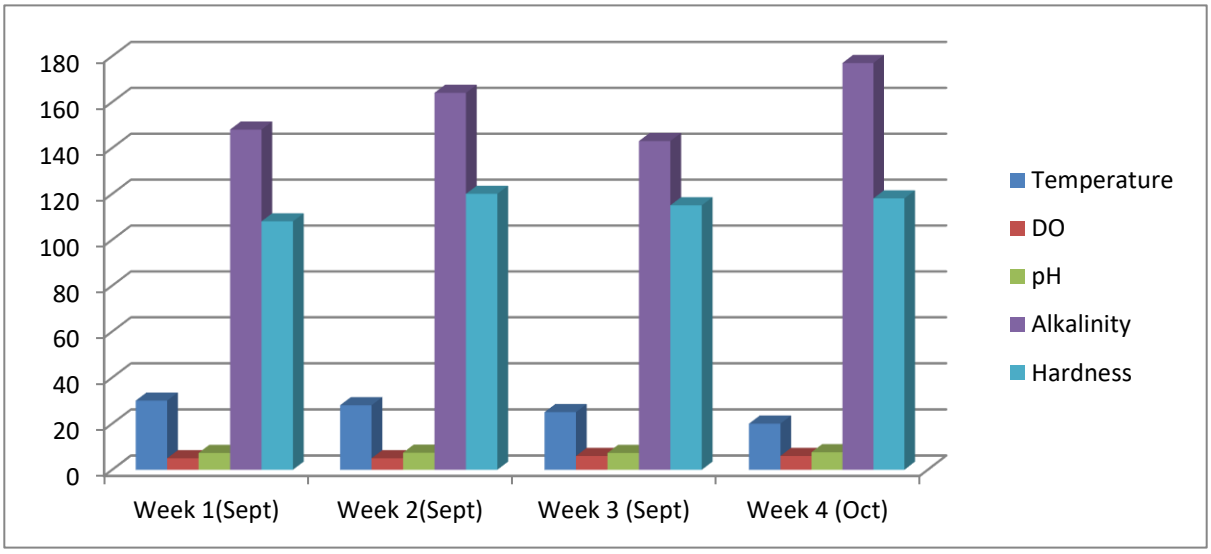

Figure 1 Physiochemical parameters recorded for brooders during broodstock management.

Length-Weight of Brooders

The measurement taken of the *C.auratus* brooders after 4 weeks of broodstock management were found to be ranging from 100-120 gram of weight and the length ranges from 22-24cm in females, while both the weight and the length of the males were measured to be lower than the females with a weight that ranges between 80-100grams and a length that varies between 18-20cm.

Table 2 Length-Weight of Brooders

Sex	**Length(cm)**	**Weight(g)**
Male		
1.	18	85
2.	20	92
Female		
1.	23	115
2.	24	119

Hormone Doses for Brooders

From the study, it was found that the given dosage, 0.5 ml/kg body weight for females and 0.2 ml/kg body weight for males of Ovafish hormone, showed satisfying results.

Table 3 Doses of Ovafish hormones for male and female brooders

Species name	Sex	No. of species	Dose (mm/g body weight)	Spawning period(in Hours)	Hatching period (in Hours)
Carassius auratus	**Male**	3	0.2	7	-
	Female	3	0.5	7	47

Table 4 Determination of Fertilization Rate

Species	Ovulation (%)	Fertilization rate (%)	Survival rate (%)
C. auratus auratius	70%	75%	65%

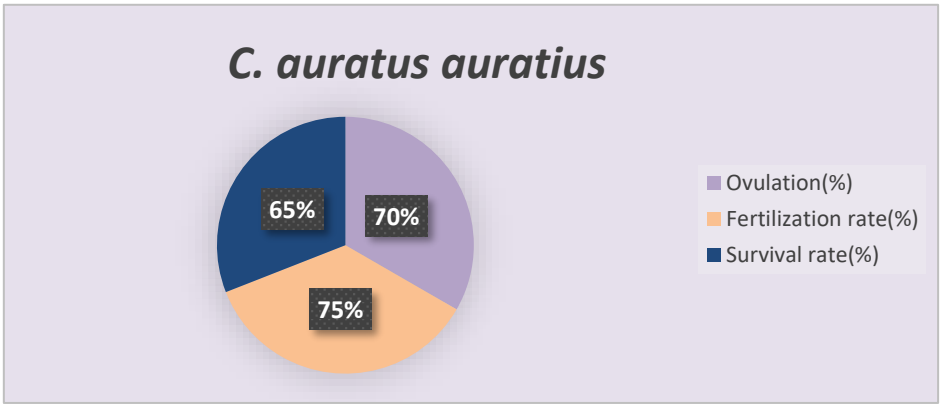

Figure 2 *C. auratus auratius*

After a certain period (1- 2 hours), the eggs were examined to observe the fertilization rate. The fertilized eggs were easily separated from the unfertilized eggs by the presence of a transparent shell with a grey or black spot within the egg shell, while the unfertilized eggs were opaque. The fertilization rate was determined using the following formula-

$$Fertilization\ rate\ (\%) = \left(\frac{No.\ of\ Fertilized\ eggs}{Total\ no.\ of\ eggs}\right) \times 100$$

$$= \left(\left(\frac{2200}{3400}\right)\right) x\ 100$$

$$= 65\%$$

3 Discussion

Goldfish have long been one of the most popular ornamental fish species among aquarium enthusiasts worldwide, especially in tropical regions. Many of the goldfish varieties available today trace their origins to parent stocks developed by breeders in China, Korea, and Japan, and these varieties are now known by various commercial names. In India, however, the technology for breeding the diverse types of goldfish is still in its early stages. Given the strong demand for goldfish in both domestic and international markets, there is a need to focus more on the breeding of multiple goldfish varieties. Breeding techniques for different goldfish types are generally straightforward and quite similar. Based on existing literature and my own research on both induced and natural breeding of comet fish, it has been found that using the appropriate hormone dosage and maintaining favorable environmental conditions significantly improves fertilization and hatching rates. It is important to avoid using steel plates for fertilization, as they can lower fertilization success and lead to the spoilage of a large number of eggs.

Using high-quality hormones in induced breeding is crucial for better outcomes. The main aim of this study was to evaluate the effectiveness of the Ovafish hormone in the induced breeding of Oranda goldfish. The experiments were carried out during September and October under controlled conditions with temperatures ranging from 20–30°C, with the ideal temperature being around 23°C. Comet goldfish breed best when this temperature range is maintained, along with light rainfall. Proper aeration was ensured in the breeding tanks. In the experiment, a single dose of Ovafish hormone was administered at a rate of 0.5 ml/kg of body weight for females and 0.2 ml/kg for males. Induced breeding occurred within six hours, while the control group females underwent natural breeding. Several factors, such as temperature, water flow rate, and water quality, can influence hatching success. The optimal temperature range for breeding goldfish is 20–28°C. Both fertilization and hatching rates were found to be slightly affected by environmental conditions and hormone concentrations.

The findings of this study suggest that induced breeding using hormones resulted in increased fertilization and hatching rates. The duration of egg incubation is heavily influenced by water parameters like salinity and temperature. At a temperature of 29°C, hatching time varied by several hours. Additionally, the condition of the broodstock also played a role in determining fertilization and hatching success.

4 Conclusion

In this study, the hormone Ovafish was used to induce breeding in *Carassius auratus*, a widely favored and economically significant ornamental fish, under controlled conditions in a cement tank. The results clearly indicate that induced breeding using Ovafish at a dosage of 0.5 ml/kg for females and 0.2 ml/kg for males led to a significantly higher breeding success rate of about 93%, compared to only 65% in natural breeding. Moreover, both the number of eggs laid and the hatching rate were notably higher in the induced breeding method. Although some commercial breeders report successful breeding without

the use of hormones, the findings of this study suggest that incorporating hormonal induction could greatly enhance their results.

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Induced breeding of *Clarias batrachus* using "gonopro-fh" in a mini portable hatchery and study on embryonic developmental stages

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Abstract

In this study the breeding of *Clarias batrachus* was carried out from July to September 2023 at Barkatullah University, Bhopal, using Gonopro-FH in a portable mini hatchery setup. Mature brooders (male: 409–545 g, female: 550–605 g) were injected intramuscularly at a 1:1 sex ratio, with carefully measured hormone doses. Fertilized eggs exhibited clear morphological features, and embryonic development was monitored from cleavage to hatching. Key developmental milestones such as the morula, blastula, gastrula, somite formation, heartbeat, and eventual hatching at 22 hours post-fertilization (25.1°C) were recorded in detail. Larval behavior, pigmentation, and organ development were also observed in post-hatching. This study concludes that hormone-induced breeding using Gonopro-FH significantly enhances spawning efficiency, fertilization rate, and seed quality. These findings support the use of synthetic hormones in this fish to achieve predictable breeding cycles, improved seed production, and sustainable aquaculture practices.

Keywords: Induced breeding, Clarias batrachus, Gonopro-FH

1 Introduction

The Asian catfish, *Clarias batrachus*, is a highly valued species in aquaculture due to its resilience, ability to survive in low-oxygen environments, acceptance of pellet feeds, rapid growth, and adaptability

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to captive conditions. Being native to Asia, it remains one of the most suitable species for aquaculture across the region. Its economic significance is notable, as it commands a high market price and is an important food fish. Studies have documented its strong production potential in aquaculture (Thakur & Das, 1986; Areerat, 1987). India, currently the third-largest fish producer and second-largest aquaculture producer globally, contributes approximately 7% to global fish production. Among aquaculture ventures, catfish farming is among the highest-yielding, with global production reaching 250 to 400 tonnes per hectare per crop (Ayyappan et al., 2006). *Clarias batrachus*, commonly known as the walking catfish or "desi magur" in India, is a freshwater, air-breathing species native to Southeast Asia. It has also been introduced in other regions, where it is sometimes considered invasive. The fish earns its nickname from its ability to move over land using its pectoral fins and body in a snake-like motion to search for food or suitable environments (Ramesh et al., 2016). It is especially popular in northeastern India due to its high consumer preference and fetches a higher price compared to carps.

Induced breeding marks a major breakthrough in aquaculture by enabling controlled reproduction in fish. It involves stimulating mature fish using pituitary or synthetic hormones to trigger the timely release of eggs and sperm in captive environments. This technique has significantly increased carp seed production in India from 6,321 million fry in 1985–86 to over 45,000 million fry in recent years. India now ranks second globally in farmed fish production. Aquaculture, the fastest-growing food sector, is expected to supply half of all fish consumed by 2025. Quality seed remains a critical factor in boosting aquaculture productivity. Induced breeding, by manipulating hormonal or environmental conditions, has become essential for producing sufficient quality seed for both artificial ponds and natural water bodies (Panigrahi et al., 2019).

Hormonal spawning techniques influence reproduction by either enhancing or suppressing biological processes. Two main approaches are used: (1) simulating the natural spawning environment, and (2) administering natural or synthetic hormones via injection or feed. Often, both methods are combined. Various hormones have been tested, but current practices highlight two cost-effective and successful approaches: (i) using gonadotropin-releasing hormone (GnRH) analogs with dopamine antagonists, and (ii) injecting purified gonadotropins such as human chorionic gonadotropin (HCG) (Kiran et al., 2016). However, in artificial breeding of *C. batrachus*, the female is stripped of eggs, and the male is sacrificed to collect milt.

Among catfish, *C. batrachus* stands out as a preferred species in Asian aquaculture due to its many advantages. Its robustness and tolerance to poor water conditions allow high-density culture and high yields. Yet, spontaneous breeding in captivity is limited, and dependence on wild seed often unreliable, time-consuming, and costly poses major challenges. Therefore, induced spawning remains the most viable method for ensuring a steady supply of quality seed for the commercial culture of this species.

2 Methodology

1. Study area

The present study was conducted in July-September 2023 at the Department of Zoology and Applied Aquaculture, Barkatullah University, Bhopal, M.P., in the hatchery. Breeding trials of *Clarias batrachus* were performed during the monsoon season.

2. Brood tank preparation

Firstly, the tank was collected and wash it with water also wash it with KMnO4 one minute second and then washed it again with water for cleaning purpose in other to prevent the germs or any kind of bacteria.

3. Collection of brooders

It has been collected from Kasturba market. For breeding purpose healthy and sexually mature broods were selected. From the market it was carried out by handling and kept them in FRP tank, it is easy process to carried brooders from market to Department because its air breathing catfish they can survive more than 16hour without water. Also, it was again treated by $KMnO_4$ and keep them for 30 minutes and control from stress or any kind of infection. After that it has been released out into the tank for one week.

4. Scientific identification of brooders

The brood fish for the artificial breeding of *Clarias batrachus* were selected from the fish market. Total 10 brooders were stock in the tank. During breeding season, the sexual dimorphism is fully prominent.

Identification of Male Fish

- **Color:** During the breeding season, the color of mature male *Clarias batrachus* changes to a grayish tone.
- **Body Shape:** Males have a noticeably slimmer belly compared to females, particularly evident during the mating period.
- **Genital Papilla:** The male's genital opening is elongated and conical in shape.
- **Dorsal Fin Spot:** Males can also be identified by the presence of distinctive spots on the dorsal fin.

Identification of Female Fish:

- **Color:** Females become darker in color during the breeding season.
- **Body Shape:** The belly of a female is broader than that of a male, a trait that becomes more pronounced during breeding.
- **Genital Papilla:** In females, the genital papilla is oval and slit-like in appearance.
- **Dorsal Fin Spot:** Females typically lack the dorsal fin spot seen in males.

5. Breeding Tank Setup

Two tanks were used in the setup. An outlet was installed at the center of the breeding tank, which is connected via a pipe to two lower-positioned tanks that act as inlets, allowing water circulation back into the breeding tank.

6. Maturity Size Requirements:

- **Fish Length:** Although this species becomes capable of breeding at around 15 cm, the ideal breeding size is between 25 to 30 cm.
- **Fish Weight:** Fish can reproduce once they reach approximately 80 grams, but the optimal brooder weight is above 100–120 grams.
- **Egg Size:** Females are considered suitable for breeding when their eggs measure between 0.12 to 0.14 cm.

7. Hormone Preparation

Brooders were injected with a hormone mixture prepared using Gonopro-FH and 0.5 ml of distilled water. A 1 ml syringe was used for injection, with the dosage calculated based on the individual fish's length and weight.

8. Injected of brooders

For induced breeding injection is the main part of successful *Clarias batrachus* breeding. First, calculate the body weight of the fish. Then use different types of synthetic hormone with different doses. For induced breeding I used Gonopro- FH injection.For both female and male given two dose, at evening time (1:30 28 Aug 2023) the first dose was given 0.5-0.6 ml/kg body weight for female and for male 0.5ml, at the ratio of 1:1 around 5-6 hours, kept in the breeding tank. It was injected again the 2nd dose was given for female 0.4ml and for male 0.3 ml. Male Magur fish’s body weight is 410gm so, the dose is <0.5 ml. and female fish is 550gm. So, the dose is 0.6 ml (about). The injection injects in the fish in 45º angle.

9. Dosage

General dose of Gonopro-FH is 0.5 ml per body weight of fish. Dose may be varied among species and location.

Female fish 0.3-0.5ml/kg body weight and Male fish 0.1-0.3ml/kg body weight.

10. During injection

Ensure that all equipment, collecting tank, syringe etc should be clean and if possible sterilized. Always handle gently to the fish. Always require quantity of Gonopro-FH withdraw trapped air from the syringe before inject. Hold fish firmly and insert needle firmly at the intra-muscular part or belly behind pelvic fin. Inject spawn Pro carefully.Gently place the fish in to breeding tank of fresh and aerated water.

11. Stripping of female

After 6 hour the female fish was stripped with hand, gently press the belly toward female genital papilla and kept in a tray. If the eggs are white that shows the immature egg. Fully mature eggs look dark brown or brownish green in colour.

12. Dissection of Male

Male have to sacrifice and remove the testis and wash it with distilled water to clean the blood and kept in the same tray and cut the testis into small pecies by scissor and crush it with pistile or hand. And eggs and milt are mixed 30-60 sec with the help of feather or brush and distilled water after mixture then gently spread the eggs in the breeding tank, and start rotated the water in the breeding tank to make the eggs rotated.

3 Results

A. Fertilized Eggs

The fertilized eggs were spherical, sticky, and brownish in color. Before fertilization, the average egg size measured approximately 0.65 ± 0.02 mm, which increased to about 1.01 ± 0.19 mm post-fertilization (refer to Figure 1).

B. Embryonic Development (Cleavage Stage)

Around 35 minutes after fertilization, the blastodisc (or polar cap) formed. The first cleavage occurred 15 minutes later, dividing the blastodisc into two cells or blastomeres. The second cleavage, occurring at a right angle to the first, happened within 55 minutes post-fertilization. The embryo reached the eight-cell stage 10 minutes after that. The fourth cleavage, parallel to the second, took place at 2 hours and 5 minutes, forming 16 cells. Four minutes later, the sixth cleavage resulted in the 32-cell stage. The morula stage was reached 2 hours and 9 minutes after fertilization, and the blastula formed at 3 hours and 17 minutes. It was observed that as cleavage progressed, the size of the blastomeres reduced.

C. Embryo Formation

At 6 hours and 10 minutes post-fertilization, the blastoderm began to spread over the yolk. By 6 hours and 30 minutes, this invasion had progressed significantly, and the eggs reached the late gastrula stage. Gastrulation was fully completed about 40 minutes later.

D. Embryo Differentiation

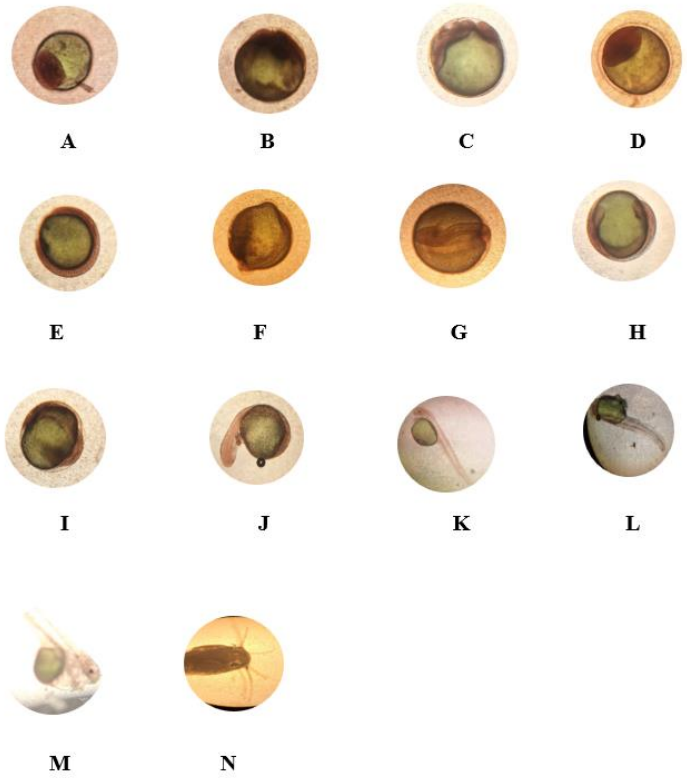
Somite formation began at 7 hours and 10 minutes after fertilization, and more developed somites were observed 13 hours in. The head and tail regions became distinguishable. One hour later, myotomes appeared, and the embryo started resembling a girdle wrapped over the yolk. As the embryo elongated, the tail separated from the yolk, and a heartbeat was detected. By 20 hours post-fertilization, tail movement and general body motion were visible. After an additional 2 hours, the yolk sac had further reduced, and the tip of the tail approached the head. By 21 hours, the embryo was fully developed and ready to hatch.

E. Hatching

At around 22 hours after fertilization, and a water temperature of 25.1°C, the elongated tail tip pushed against the egg's head end, breaking the shell. The head emerged first, followed by the rest of the body as the larva wriggled free from the egg case (see Figure 1).

F. Larval Development

The newly hatched larvae had unpigmented eyes, lacked fin buds, and did not yet have a functional mouth. The anus was located just behind the yolk sac, which protruded near the front end of the larva. Black pigment cells appeared in the fin folds, except at the caudal tip, and were also scattered on the yolk, head, and body. The larvae swam slowly upward before sinking and suspending themselves in an inclined, head-down position in the water column. As development continued, the eyes became fully pigmented and the pectoral fins elongated. The mouth opened, and the esophagus became clearly visible. Pigmentation increased, especially around the tail and caudal peduncle. A few melanophores were present near the posterior gut. The yolk sac was nearly absorbed, leaving only a small remnant. The larvae began slow, deliberate movements with occasional jerks, swimming both near the surface and along the bottom of the water column.



Length and Weight of mature brooders:

At the end of the brood stocking management, it was found that the brooders (Male and Female) grew higher than before collection. Length of the *Clarias batrachus* is below 20-25 cm (both male and female), whereas, weight of the female is 550- 605 g and the male 409-545 g.

TABLE 1: Length and Weight of brooder fish before injection (23-9-2023)

Sex	Length (cm)	Weight (gm)
Female	15.0	550
Male	13.2	410

1. **Doses for female and Male:**

From the study, a ratio of 1:1 were mature fish injected by using GONOPRO-FH hormones, brood fishes were feed in the brood rearing tank by provided artificial diet for good health and full maturation.

TABLE 2: Doses of GONOPRO-FH for Female and Male:

Species name	**Sex**	**No. of Species**	**1st dose (ml/kg nody weight)**	**2nd dose (ml/kg body weight)**	**Hatching time (hour)**
Clarias batrachus	**Female**	**1**	**0.6**	**0.4**	**72-78**
	Male	**1**	**0.5**	**0.3**	

2. **Fertilization rate, Unfertilization rate, Survival rate and Mortality:**

From the experiment, the data has been found that:

TABLE 3: Experiment data of Fertilization rate and Unfertilization rate:

Species name	**Fertilization rate%**	**Unfertilization rate%**
Clarias batrachus	75%	25%

TABLE 4: Experiment data of Survival rate and Mortality:

Species name	**Survival rate%**	**Mortality rate%**
Clarias batrachus	**10%**	**90%**

TABLE 5: Mean of Fertilization rate(%) and Survival rate(%):

a. **Fertilization rate (%)= No. of fertilized egg × 100**

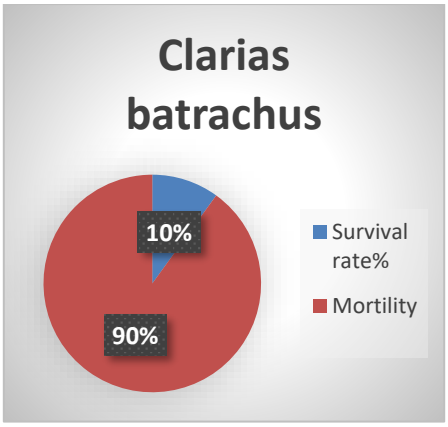
Total no. of egg

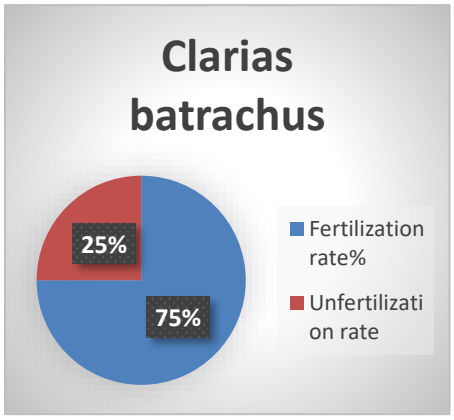
= 75%

b. **Survival rate (%)= No. of survival fry × 100**

Total no. of hatching

= 10%





DISCUSSION

In the current study, GONOPRO-FH was effectively used to induce breeding in *Clarias batrachus*, a commercially important catfish species. The process showed positive stripping responses and led to increased egg production and fertilization rates, although the hatching and survival rates were comparatively lower. The optimal results were obtained when female brooders were injected with a

hormone dose of 1 ml/kg body weight, likely due to the complete maturity of the eggs. Typically, male brooders are sacrificed during the breeding process because they produce very little milt. The sperm is extracted through an incision and mixed with the eggs collected from females by stripping. The hormone dose likely stimulated the female brooders effectively by inducing contraction in the smooth muscles of the gonoduct before ovulation, contributing to the overall breeding success.

The latency period (time between injection and ovulation) ranged from 11 to 23 hours. The fertilized eggs of *Clarias batrachus* were found to be adhesive and demersal (settling at the bottom), similar to those of other catfish species like Mystus montanus, Pangasius sutchi, and Heteropneustes fossilis. In contrast, unfertilized eggs appeared pale and opaque. This adhesive nature of the eggs is an adaptive feature that prevents them from being carried away by water currents and helps ensure proper oxygen availability. In this study, the fertilized eggs appeared yellowish-brown, which is consistent with observations made by Khan and Thakur. It was also noted that the hatching time decreased with increasing water temperature, regardless of the hormone type or dosage used. This observation aligns with findings reported by researchers like Zaki, Abdula, and Herath.

Overall, the induced breeding technique using Gonopro-FH has proven to be a valuable advancement in the culture of *Clarias batrachus*. This method is gaining widespread adoption and is expected to significantly improve the availability and quality of fish seed in the near future. The outcomes of this study will contribute greatly to the production of quality seed, enhancing induced breeding practices and promoting the sustainable culture of this important fish species.

CONCLUSION

This study concludes that induced breeding not only enhances the quality of fish seed but also increases the overall yield and provides better control over the breeding process. It enables the production of desired quantities of spawn at any time and ensures genetically pure offspring of specific cultured fish species. In this research, the synthetic hormone Gonopro-FH proved to be both effective and dependable for the induced breeding of *Clarias batrachus*. This technique can support breeding efforts and contribute to the sustainable cultivation of this important fish species.

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Induced breeding of medicinal fish *Heteropneustes fossilis* by using ovatide

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Abstract

The present study explores the induced breeding of *Heteropneustes fossilis*, a commercially and medicinally valuable freshwater catfish, using the synthetic hormone Ovatide under controlled hatchery conditions. Conducted between July and December 2022 at the Department of Zoology and Applied Aquaculture, Barkatullah University, Bhopal, the breeding trials were carried out during the monsoon season. Healthy, mature brooders were sourced from local markets and departmental ponds, then acclimatized and maintained for two months in treated tanks. Water quality parameters were regularly monitored and optimized for breeding. Brooders were fed a nutritionally rich artificial diet and managed in tanks with aquatic vegetation (Hydrilla and Pistia) to support egg adhesion. Brooders exhibited growth during the management phase, with females reaching 40–60 g and males 30–50 g. Hormonal induction was performed with intramuscular injections of Ovatide at dosages of 1 ml for females and 0.5 ml for males, followed by hand stripping and artificial fertilization. Fertilized eggs were incubated under controlled conditions with continuous water flow and oxygenation to enhance survival and hatching rates. Results showed successful fertilization (80%) and survival (50%), with eggs adhering to aquatic weeds and developing under incubation. The study demonstrated that induced breeding using Ovatide is an effective method for the mass production of *H. fossilis* seed. This technique ensures a reliable and timely supply of quality fish seed, offering a strategic approach for the conservation, commercial cultivation, and sustainable management of this important indigenous species.

Keywords; Induced breeding, Heteropneustes fossilis, ovatide.

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1 Introduction

Heteropneustes fossilis (Bloch, 1794), commonly known as the singhi or stinghi catfish, belongs to the sub-order Siluroidei and family Sacchobranchidae. It is considered a highly suitable species for aquaculture due to its commercial importance. In the Indian subcontinent, this species is highly valued by consumers for its nutritional and medicinal properties, often commanding premium prices. It makes up a significant share of India's air-breathing fish production, which currently relies largely on capture fisheries (Nayak et al., 2018). However, the lack of readily available seed has posed a major challenge for its cultivation. To address this issue, the ICAR-Central Institute of Freshwater Aquaculture has successfully developed a standardized breeding and seed rearing technique for *H. fossilis* to meet increasing demand among fish farmers (Sahoo et al., 2018). The species is typically found in ponds, swamps, ditches, and marshes, and can also survive in muddy river environments. It is an omnivorous fish and can tolerate mildly brackish waters. Singhi generally spawns in confined waters during the monsoon season, but it can also breed in derelict ponds and ditches with sufficient rainwater (Kiran et al., 2016).

Notably, the singhi catfish can inflict a painful sting on humans through a venom gland located on its pectoral fin spine. The species can grow up to 30 cm in length and holds considerable value in local fisheries, aquaculture, and the ornamental fish trade (Rainer & Pauly, 2011). Its rapid growth, adaptability to dense stocking, resilience in oxygen-deficient water, low fat content, high protein and iron levels, and medicinal benefits make it an ideal candidate for aquaculture (Rahmatullah et al., 2016). Farming this species not only supports increased fish production but also contributes to the conservation of its declining wild populations. In Bangladesh, *H. fossilis* is known as shingh and is a widely favored air-breathing catfish. Its popularity among farmers has been growing steadily due to its profitability and hardy nature. However, the degradation of natural habitats has made it increasingly difficult to source fry from the wild. Though capture fisheries were the primary source of fry and fingerlings in the past due to limited hatchery infrastructure, the advancement of induced breeding techniques has significantly improved seed availability in Bangladesh. Despite this progress, hatchery management challenges such as poor practices, genetic depression, and unintended hybridization have affected seed quality.

Induced breeding has become a vital component of aquaculture, especially in composite fish farming systems (Saha, 1995). Hormonal spawning techniques play a critical role by influencing the reproductive process at multiple stages, either enhancing or suppressing it. There are two primary strategies in induced breeding: the manipulation of environmental conditions to replicate natural spawning cues and the administration of reproductive hormones or synthetic analogs through injections or diet. These strategies are often used together for greater effectiveness. Several hormones have been used successfully in aquaculture, but recent research and commercial practices highlight two main approaches as being the most cost-effective and efficient: (i) the use of GnRH analogs combined with dopamine antagonists, and (ii) injections of purified gonadotropins, such as human chorionic gonadotropin (hCG).

Understanding the embryogenesis of *Heteropneustes fossilis* is crucial for improving artificial propagation, growth rates, farming practices, and understanding species-specific biological traits and environmental requirements (Borcato et al., 2004). The early life stages—embryonic and larval—are particularly sensitive to environmental changes and are vital for studying developmental biology (Verreth et al., 1992). Gaining insights into these stages is essential for enhancing larval survival and growth and for optimizing aquaculture systems. Consequently, the present study aimed to explore the detailed embryonic and larval development of *H. fossilis* under controlled hatchery conditions.

A. Methods and Materials

1. Study area

The present study area was conducted in July-December 2022 at the Department of Zoology and Applied Aquaculture, Barkatullah University, Bhopal, M.P., in the hatchery. Breeding trials of *Heteropneustes fossilis* were performed during the monsoon season.

2. Tank preparation and Collection of brooders

Firstly, the tank was collected and wash it with water also wash it with KMnO4 and then washed it again with water for cleaning purpose in other to prevent the germs or any kind of bacteria. It has been collected from Kasturba market and from ponds in the department with the help of hand-net or small basket. From the market it was carried out by handling and kept them in hundies or basket, it is easy process to carried brooders from market to Department because its air breathing catfish they can survive more than 16 hours without water. Also, it was again treated by KMnO4 for 2 minutes per each brooder. So, as to keep them and control from stress or any kind of infection. After that it has been released out into the tank for two months (July – August).

3. Brood collection

The brood fish for the artificial breeding of *H.fossilis* were obtained from the respectively fish market. And a total of 25 brooders were stock in the tank. By which the mature female fishes can be identified through big-jelly like type and swollen abdomen where, as mature male fish is flattened and pointed genital papillae All the brood-stocks were acclimatized before the induced breeding procedures and were kept separately in tank.

4. Brood stock management

In the experiment of the breeding period, brood stock management has been done for 2 months (July-August, 2022)

I. **Water quality:** During the experimental period different physical and chemical parameters (flow rate, temperature, pH, dissolved oxygen, free carbon dioxide, hardness and alkalinity, nitrate, nitrite, total ammonium, phosphate, iron and calcium) of brooders tank water and hatchery water were analyze as per the standard methods. Water is the most deciding crucial parameters which is very important for fish breeding.

i. **Feeding methods:** The brood fishes were fed on supplementary died from rice bran 20%, mustard oil cake 4%, 1% vitamin premix, earthworm, snail, white portion of boil eggs etc. the brooders were also treated with cow dung and soil manure respectively.

ii. **Length and weight measurement:** During the month of July and August the fish weight has been attained 40-60 gram for female and 30-50 grams male, and the length has measured with scale approximately 19-23 cm.

Aquarium preparation: Two aquariums were prepared before, that is breeding tank and control tank.

- **Breeding tank:** from the breeding tank brooders after injected were keep together both males and females so that they can reproduced along with the aquatic weed (ceratophylum & pistia), as eggs of *H. fossilis* is adhesive and cannot seen by naked eyes.
- **Control tank:** From the control tank brooders after they release (eggs and sperm), were collected it in the breeding tank and transfer into the control tank, as *H. fossilis* is a carnivores they can be eaten their own eggs.

iii. **Hormones preparation:** Brooders were injected using the syringe injection made with 0.5 mm Ovatide and 9.5 mm distilled water in a 1 ml syringe, depending on the length and weight size of fishes.

iv. **Injected of brooders:** Brooders were injected in intra-muscular part it is generally given in the muscle below the tip of the dorsal fin, at a 45' angle. At evening time (7:30. 28-aug-2022) with a dosage of 1 ml for females and 0.5 mm for males at the ratio of 3:3 around 10-11 hours, kept with the unwanted plants (aquatic weed like hydrilla, pistia etc). It was injected again using the same dosage of hormones for both males and females around 5 hours, and further proceeded to stripping procedure.

v. **Stripping methods:** The female fishes were stripped using with hand and kept in a tray and male were incised and take out the sperm in a tray. Further, it was mixed both the milt and eggs in a tray with the help of feather and distilled water, washed it with water several times and kept in an aquarium for the incubation period. And then continuous showering water for oxygenation in order to fertilized and again further proceed to survival rate.

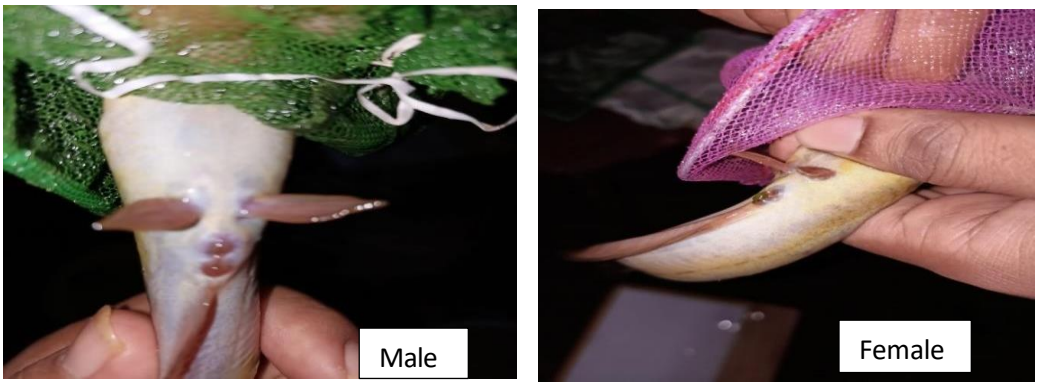

Figure 1 Showing mature Female & Male (*Heteropneustes fossilis*)

2 Results

a) **Water quality parameters:** All importance water quality parameters of different setup during breeding trials were monitored regularly and also kept recorded especially during brood stock management in two months (July-August 2022). These include: pH, Temperature, Alkalinity, Hardness, Carbon dioxide levels etc

Table 1 Physico-chemical parameters recorded of brooders during brood stock management (July-august 2022).

Parameters	Week 1 July	Week 2 July	Week 1 August	Week 3 August
pH	7	6	7	8
Temperature (°C)	30	28	29	28
Alkalinity (mg/L)	156	148	128	126
Hardness (mg/L)	110	126	126	132
Dissolve Oxygen (PPM)	5	5	4	5

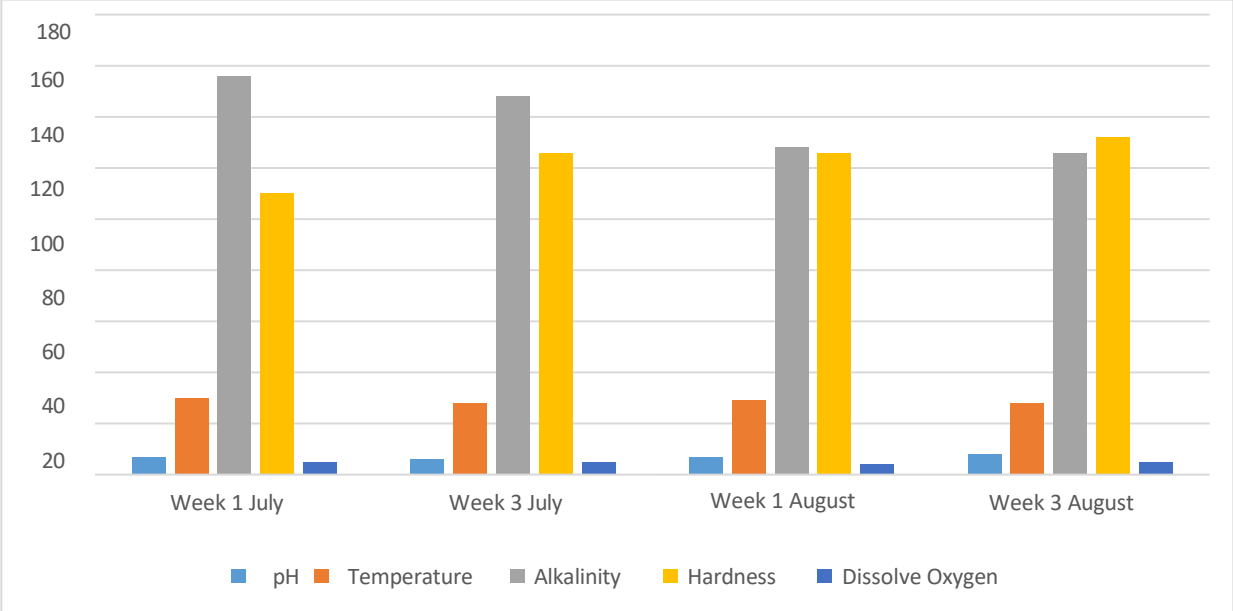

Figure 2

b) Length and Weight of the mature brooders

At the end of the brood stocking management, it was found that the brooders (Males and Females) grew higher than before collection. The length of the *H. fossilis* ranges 16-21 cm (both male and female), whereas, weight of the females is 40-60 grams and males 30-50 grams.

Table 2 Length and Weight of Brooder fish before injected (28-08-2022).

Sex	Length (cm)	Weight (g)
Female	21	57
Male	20	39

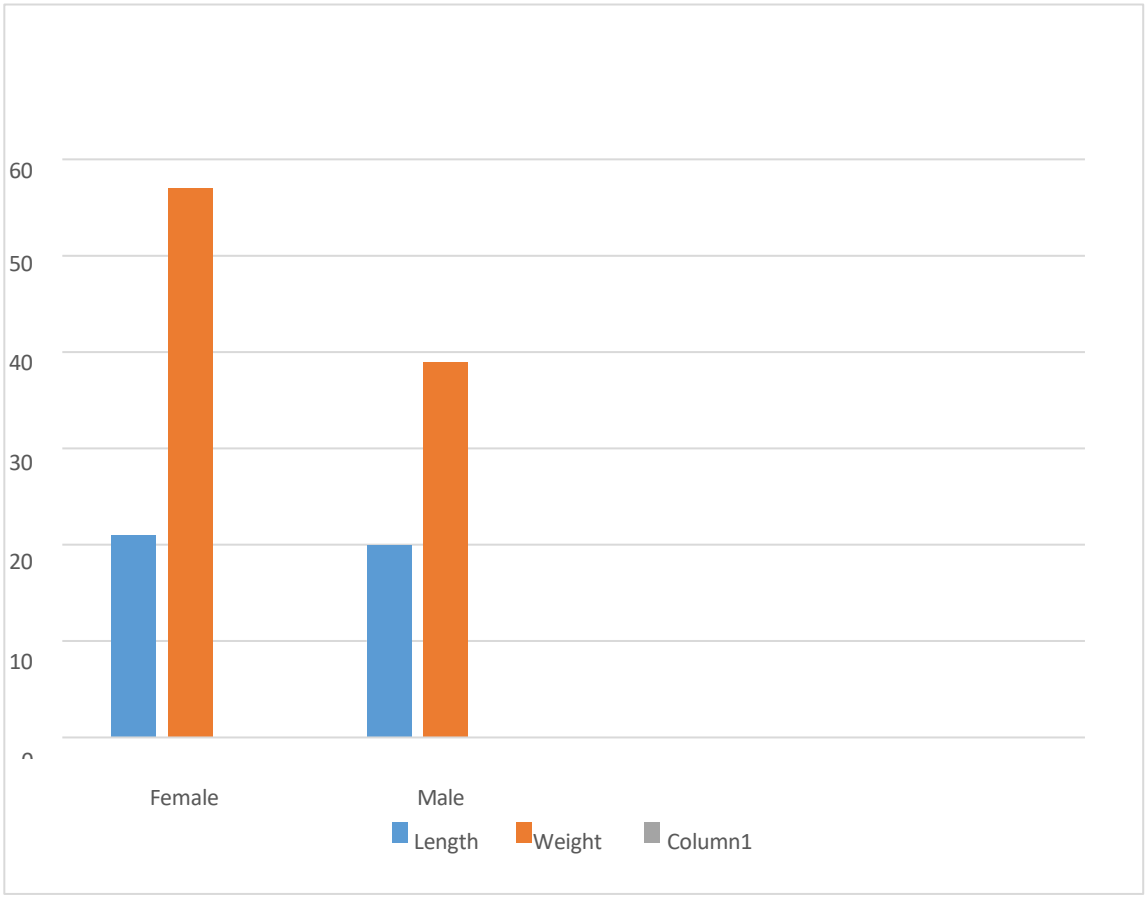

Figure 3: Showing variation of length and weight mature *H. fossilis* (Female and male)

c) Doses for females and males: From the study, ratio 3:3 were mature fish injected by using ovatide hormones. Brood fishes were feed in the brood rearing tank by provide artificial diet for good health and full maturation.

Table 3 Doses of ovatide hormones for female and male.

Species name	Sex	Number of species	1st dose (mm/g body weght)	Intervals	2nd dose (mm/g body weight)	Intervals	Hatching time (hours)
Heteropneustes fossilis	Female	3	1	11	1	5	72-78
-	Male	3	0.5	11	0.5	5	-

d) Fertilization rate and survival rate: From the experiment, the data has been found that

Table 4: Mean of fertilization rate (%) and survival rate (%). Whereas, the fertilization rate

Species	Ovulation rate %	Fertilization rate %	Survival rate %
Heteropneustes fossilis	75%	80%	50%

Survival rate was calculated by using the following formula:

a) Fertilization rate (%) = No. of fertilized eggs

   Total no. of eggs = 80%

b) Survival rate (%) = No. of survival fry

c) Total no. of hatching = 50%

3 Discussion

In the present investigation, the fertilization rate was recorded 80% with the survival rate of 50%. The current result is also supported by the report of Haniffa & Sridar (2002) on *Heteropneustes fossilis* where they recorded fertilization rate of 85% and survival rate of 60% respectively. However, in some earliest studies, there are reports of higher fertilization and hatching rate in *H. fossilis* (Rahman et al 2013). The variation in fertilization and hatching rate is might be due to difference in environmental conditions particularly water temperature and precipitation during the study period. From the study, the breeding pattern of induced breeding in *Heteropneustes fossilis*, it has been observed and learnt that it creates and important part for fish culture, by injection the fish using ovatide hormones. The use of this techniques is growing tremendously as expected in near future that there is every possibility of fish seed quality. Mostly, male brooder used to sacrifice during breeding because it contains very low of milt by incised and take out the sperm and mixed it with eggs, whereas females proceed by stripping. The dependence on artificial breeding of fishes will be felt all the more by apprehend that in future, will be improve more and more and the chance of procuring sufficient quantity of fish seed. It is the fact that the requisite for successful induced breeding is an assured supply of pure quality of fish seed. It has been found that it

has more profitability be utilized in using this technique to breed and obtain seed for fish farming. The experiment studied have been highly encouraging and hence show great promises for further purpose.

4 Conclusion

The use of induced breeding techniques presents new possibilities and advancements in the field of aquaculture. It enables the production of pure spawn for specific fish species under cultivation and allows for multiple breeding cycles within a single year. Unlike natural conditions where seed availability is unpredictable, induced breeding ensures a consistent and timely supply of quality seed, capable of meeting demand at any time. Further improvements in this technique can be achieved by carefully managing key factors such as temperature, water hardness, pH, circulation, and hormone dosage. It is also essential to use healthy broodstock and maintain suitable environmental conditions for both brooders and their offspring. This study contributes significantly to addressing the shortage of fish seed and supports strategic planning for the conservation and sustainable culture of valuable indigenous fish species in the future.

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Induced breeding of stinging catfish, *Heteropneustes fossilis* using Gonopro-fh in mini portable hatchery and extension education

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Abstract

The present study focused on the induced breeding of *Heteropneustes fossilis* (stinging catfish) using the synthetic hormone Gonopro-FH in a mini portable hatchery setup, conducted between August and December 2023 at the Department of Zoology and Applied Aquaculture, Barkatullah University, Bhopal, Madhya Pradesh. A total of 20 healthy brooders were collected, acclimatized, and managed in hygienically prepared tanks. Broodstock were fed a supplementary diet rich in protein and micronutrients to promote gonadal development. The breeding system comprised a specially designed four-tank setup, with an elevated incubation tank facilitating a circular water flow pattern to mimic natural conditions and ensure proper oxygenation. The inner incubation chamber was equipped with a plankton net and vertical outlet for safe egg retention and water exchange. Induced breeding was initiated through intramuscular injections of Gonopro-fh at doses of 0.6 ml for females and 0.4 ml for males. After a latency period of eight hours, females were stripped of eggs, and testes from males were extracted. Fertilization was achieved through manual mixing with distilled water, and the fertilized eggs were incubated in the mini hatchery with continuous water flow. Additionally, as part of an extension education initiative, field demonstrations and training programs were conducted in Behrawal (Shajapur) and Berasia (Bhopal). These sessions aimed to transfer knowledge on induced breeding, hatchery management, and modern aquaculture techniques to rural farmers, enhancing local capacity for sustainable fish farming. This integrated approach not only demonstrated the effectiveness of portable

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hatchery systems for *H. fossilis* but also contributed to rural development and food security through skill enhancement and technology dissemination

Keywords: Induced breeding, Extension Education, Heteropneustes fossilis.

1 Introduction

Heteropneustes fossilis (Bloch, 1794), commonly referred to as 'singhi' or 'stinghi catfish,' belongs to the sub-order Siluroidei and the family Sacchobranchidae. This species is considered highly suitable for aquaculture due to its strong consumer demand in the Indian subcontinent, owing to its nutritional and medicinal benefits, as well as its high market value. At present, the majority of its production in India is sourced from wild capture fisheries (Nayak et al., 2018), and the limited availability of quality seed poses a significant challenge to its cultivation. To address this issue, the ICAR-Central Institute of Freshwater Aquaculture has developed a standardized protocol for seed production of *H. fossilis* to meet the growing needs of fish farmers (Sahoo et al., 2018).

This species is typically found in natural habitats such as ponds, marshes, ditches, swamps, and occasionally in muddy rivers. It is omnivorous and capable of surviving in slightly brackish waters. Naturally, *H. fossilis* breeds during the monsoon season in confined water bodies, though it can also reproduce in neglected ponds and ditches that accumulate rainwater (Kiran et al., 2016). The singhi catfish is known to inflict a painful sting through venom glands located on its pectoral fin spines. It can grow up to 30 cm in length and is an important component of local fisheries, aquaculture operations, and the ornamental fish trade (Rainer & Pauly, 2011). Its accessory respiratory organ allows it to survive for up to 16 hours out of water, as it does not come into direct contact with the aquatic environment (Mondal et al., 2018).

Induced breeding has emerged as a highly effective technique in aquaculture, especially within composite fish culture systems (Saha, 1995). Hormone-induced spawning works by regulating various stages of the reproductive cycle, either stimulating or inhibiting specific processes. Two main strategies are employed: (1) environmental manipulation to simulate natural spawning conditions, and (2) administration of natural or synthetic reproductive hormones through injection or diet. Often, these methods are used in combination to enhance success. Recent studies and industry practices have highlighted two particularly effective hormone-based approaches: the use of GnRH analogs with dopamine inhibitors and gonadotropin-based injections, as cost-efficient and successful methods for induced spawning. Understanding the embryonic development of *H. fossilis* is essential for advancing artificial breeding efforts, enhancing growth rates, improving farming practices, and gaining insight into species-specific adaptations and habitat preferences (Borcato et al., 2004). The early life stages, embryonic and larval, are also highly responsive to environmental changes, making them important for studying developmental biology and evolutionary relationships (Verreth et al., 1992). Such knowledge is crucial for optimizing larval survival and overall productivity. Hence, this study aims to explore the embryonic and larval development of *Heteropneustes fossilis* under controlled hatchery conditions.

Mini Portable Hatchery

Fig-1: Mini-portable hatchery

Fig-2: Breeding tank

Pattern

Four tanks were taken, an outlet was created at the centre of the two brown tanks and connected with a pipe to the other two black tanks, which are also the inlet of the breeding tank. The breeding tank is elevated slightly above the inlet tank. The breeding or incubation tank consists of two compartments. The inner compartment is equipped with a vertical outlet pipe measuring 2 cm in diameter, featuring holes at various levels to allow excess water to drain out. To prevent the loss of eggs and hatchlings, the walls of the inner chamber are lined with a plankton net.

Working

After mixing milt and eggs, the mixture is dispersed in the breeding tank for incubation. With the help of a motor, the water is pumped up from the inlet tank to the breeding tank. The inlet pipe is positioned 45˚ angle to the wall of the tank for circular motion of water to recreate natural water movement.

2 Methodology

Study area

The present study was conducted in August-December 2023 at the Department of Zoology and Applied Aquaculture, Barkatullah University, Bhopal, M.P., in a portable mini hatchery. Breeding trials of *Heteropneustes fossilis* were performed during the monsoon season.

Fig-3: *Heteropneustes fossilis*

1. Tank preparation and Brood collection

Firstly, the tanks were collected and washed with water and then rinsed with KMnO4 and again rinsed with water in other to prevent germs or any kind of bacteria. The brood fish for the artificial breeding of *H. fossilis* were obtained from Kasturba fish market. And a total of 20 brooders were stock in the tank. Before stocking, the brooders were treated with KMnO4 for 2 minutes per each brooder with the purpose of keeping them from stress or any kind of infection. The mature female fishes can be identified through big-jelly like and swollen abdomen whereas mature male fishes has flattened and pointed genital papillae. All the brood-stocks were acclimatized before the induced breeding procedures and kept separately in tanks.

2. Brood stock management

The brood fishes were fed on supplementary diet from rice bran 20%, mustard oil cake 4%, 1% vitamin premix, earthworm, snail, white portion of boil eggs etc. the brooders were also treated with cow dung and soil manure respectively.

3. Breeding tank (Mini portable hatchery) preparation

Four tanks were taken, outlet is created at the centre of the two brown tanks and connected with a pipe to the other two black tanks which is also the inlet of the breeding tank. The breeding tank is elevated slightly above the inlet tank. There are two chambers in the breeding/incubation tank. The inner chamber is provided with 2cm. diameter vertical outlet with holes at different heights for taking out excess water from the incubation tank. The wall of the inner chamber is covered with plankton net to prevent the escape of eggs and spawns.

4. Hormones

Brooders were injected with Gonopro-FH hormones, and the doses were calculated according to the weight of the fish.

5. Injection of brooders

At a ratio of 1:1, both females and males have been administered intramuscularly synthetic hormone Gonopro-FH at respective doses of 0.6 ml and 0.4 ml as well as preserved in the breeding tank (portable mini hatchery). After 4 hours second dose was administered to both male and female.

6. Stripping methods

After an eight-hour latency period, the female was stripped of eggs, while the male was euthanized to extract the testes. The eggs and spermatozoan were mixed and sufficient distilled water were added to activate the spermatozoan and the mixture is spread in the breeding tank for incubation. And then a continuous shower of water is provided for oxygenation.

Fig-4: Brood tank preparation

Fig 5: Brood collection

Fig-6: Brood selection

Fig-7: Breeding tank preparation

Fig-8: Hormones

Fig-9: Weighing of fish

Fig-10: Stripping of female

Fig-11: Injecting of brooders

3 Results

a. Doses for females and males

Table-1: Doses of Gonopro-FH hormones for male and female of *H. fossilis*

Species name	Sex	Number of Species	Length (cm)	Weight (g)	1st Dosage (ml/kg Body weight)	2nd Dosage (ml/kg Body weight)	Latency period(hrs.)
Heteropneustes fossilis	Male	1	18.8	33.8	0.03	0.02	-
	Female	1	24.4	65	0.04	0.06	12-14

4 Fertilization Rate and Survival Rate

a. Fertilization rate (%) $= \frac{\text{No.of fertilized eggs} \times 100}{\text{Total no. of eggs}}$

b. Survival rate (%) $= \frac{\text{No.of survival fry} \times 100}{\text{Total no. of hatching}}$

Table-2: Fertilization rate and Unfertilization rate of *H. fossilis*

Species name	Fertilization rate (%)	Unfertilized rate (%)
Heteropneustes fossilis	70%	30%

Table-3: Survival rate and Mortality of *H. fossilis*

Species name	Survival rate (%)	Mortality rate (%)
Heteropneustes fossilis	15%	85%

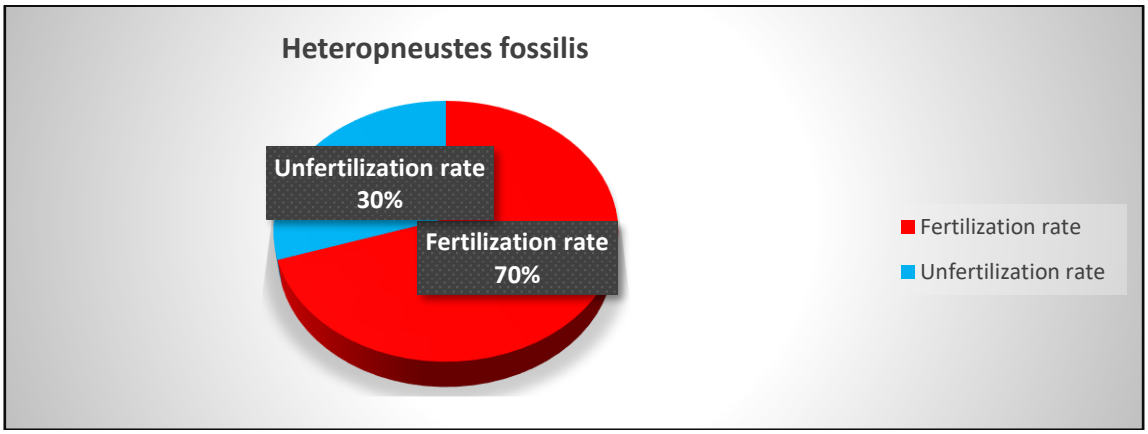

Fig-12: Pie chart of Fertilization rate and Unfertilization rate

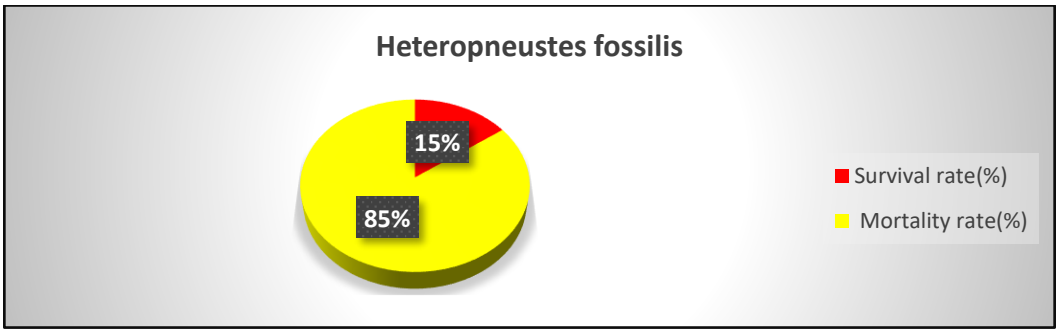

Fig-13: Pie chart of Survival rate and Mortality rate

5 Extension Education

Farm extension services are crucial for the advancement of agriculture-based communities. The cultivation of both shellfish and finfish in aquaculture is increasingly acknowledged as a key strategy for promoting rural development and ensuring food and nutritional security for rural populations. Two places, Behrawal (Shajapur) and Berasia (Bhopal), were selected for the study. Training on induced breeding, breeding techniques and demonstration of a mini portable hatchery. The purpose of the training was to: upgrade their existing operation farm management skill, enhance their skills and knowledge, utilized their pond area for modern fish culture, and improve productivity and ultimately lead to rural development.

Fig-14: Training on Induced Breeding

Fig-15: Demonstration of mini portable hatchery in Semra Kalan

Fig-16: (a and b): Demonstration of mini portable hatchery in Behrawal

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Polyculture of small fish species (*Systomus sarana, Pethia ticto and Rasbora daniconius*) with Indian Major Carps

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Abstract

The present study aimed to evaluate the growth performance and survival of small indigenous fish species *Systomus sarana, Pethia ticto, and Rasbora daniconius* in polyculture with Indian Major Carps (IMCs) including Labeo rohita, Catla catla, and Cirrhinus mrigala. The experiment was conducted from August to December in the Shade-II hatchery of the Department of Zoology and Applied Aquaculture, Barkatullah University, Bhopal. Two treatments were designed: Treatment-1 (T1) consisted of both IMCs and small fish species, while Treatment-2 (T2) included only the small fish species. Each tank held 60 individuals, and both were managed under similar feeding, fertilization, and water quality monitoring protocols. Water quality parameters such as temperature, pH, dissolved oxygen, free CO_2, total alkalinity, and hardness remained within optimal ranges for fish growth throughout the culture period. The final average weights of small fish species were slightly higher in T2 (e.g., *Rasbora daniconius* 9.41 g) compared to T1 (9.29 g), suggesting mild competition for resources in the mixed stocking environment. Among IMCs, Cirrhinus mrigala exhibited the highest growth (13.47 g). Survival rates were high in both treatments, with T2 showing a slightly better average (86.6%) than T1 (82.35%). The results indicate that small indigenous fish species can be co-cultured with IMCs without significantly compromising their growth or survival, offering a promising approach for enhancing fish yield and biodiversity in freshwater aquaculture systems.

Keywords: Polyculture, Small fish species, Indian Major Carps

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1 Introduction

Aquaculture has emerged as a rapidly expanding industry due to the rising global demand for fish and seafood (Cao et al., 2007), now accounting for approximately 46% of the total food fish supply (Nyanti et al., 2012). Beyond meeting dietary needs, aquaculture plays a significant role in generating employment opportunities, especially in rural communities. Fish serves as a vital source of animal protein and is considered one of the most efficient systems for producing protein-rich food from aquatic resources. It complements the carbohydrate-dominated diets prevalent among many low-income populations in developing nations.

Fish and fisheries contribute substantially to food security, with small-scale fisheries holding particular importance, as highlighted by the Food and Agriculture Organization (FAO, 2003). Among the various aquaculture methods, polyculture is notably effective in increasing yield. This technique, which involves raising multiple fish species together, utilizes natural food resources in ponds more efficiently than monoculture systems, especially in extensive and semi-intensive setups (Jhingran, 1982; Lin, 1982; Hassan, 1990; Hassan et al., 1997). Successful polyculture depends on selecting species with diverse feeding habits and stocking them in suitable combinations and proportions (Halver, 1984). Ahmed (1992) emphasized the importance of Indian major carps rohu (*Labeo rohita*), catla (*Catla catla*), and mrigal (*Cirrhinus mrigala*) in polyculture systems. Additionally, small indigenous fish species (SIS), typically growing to less than 25 cm (or 9 inches), contribute significantly to nutrition and livelihoods, especially among the poor and marginalized. Popular SIS species like mola (Amblypharyngodon mola), chapila (*Gudusia chapra*), tengra (*Mystus vittatus*), pabda (*Ompok pabda*), colisha (*Colisa fasciata*), punti (*Puntius sophore*), and chela (*Chela cachius*) are in high demand in both rural and urban markets.

Most SIS species are under 10 cm in length and are usually consumed whole, including bones and organs. These fish are rich in calcium and are likely good sources of iron and zinc (Tripathy, 1997). Certain species, such as *Amblypharyngodon mola*, *Osteobrama cotio*, and *Rasbora daniconius*, also provide significant amounts of vitamin A (Thilsted et al., 1997). Most of the SIS have a short life cycle and require only a few months to grow to sexual maturity. Many SIS have a fast growth rate and a good food conversion ratio (Rajts et al., 1997). SIS are often more hardy and resistant to water quality and temperature fluctuations than the species of Indian carp (Akhteruzzaman et al., 1997). The black line *Rasbora*, *Rasbora daniconius*, is a popular indigenous ornamental fish of India (Mahapatra et al., 2004; Mahapatra et al., 2005). Its body is compressed and oblong. It is also a popular food fish for economically weak communities because of its low price (Kumar et al., 2006). The ticto barb, *Pethia ticto* (Hamilton, 1822), is one of the Cyprinid fish species. It is a small, indigenous and admirable fresh and brackish water popular fish species. It is commonly known as “ticto” or “two-spot barb”. The *P. ticto* is a valuable fish food item and an important source of micronutrients essential in preventing malnutrition and vitamin and mineral deficiencies in rural communities. *Systomus sarana* (Hamilton, 1822) is a member of the family Cyprinidae, commonly known as “Olive barb” The conservation status of the fish has been referred to as critically endangered (IUCN Bangladesh, 1998; Ameen et al., 2000; Hussain and Mazid,

2004). It is a tasty, the most popular and favourite table fish among barb species, having high nutritional and market value in Bangladesh as well as other Asian countries (Chakraborty et al., 2006).

Despite their relatively small size (100–200 grams), the strong consumer demand for these species makes them ideal candidates for expanding carp farming (Gopakumar et al., 1999; Chakraborty et al., 2003). Fish farming plays a crucial role in enhancing people's nutritional intake and in the efficient use of water and land resources (Abbas et al., 2010; Sarker et al., 2014). It also stimulates the development of related industries. The polyculture of Indian Major Carps (IMC) such as Labeo catla (*Catla*), Labeo rohita (*Rohu*), and Cirrhinus mrigala (*Mrigal*) is a common and effective practice, as these species naturally occupy different ecological zones within water bodies. Rather than removing native small indigenous species (SIS) from aquaculture systems, efforts should be made to maximize their production, as they utilize otherwise untapped food sources and ecological niches in ponds (Roos, 2001; Ross et al., 2003). Historically, SIS were plentiful in rivers, ponds, streams, beels, ditches, and floodplains, but their populations have declined due to habitat destruction, overfishing, pesticide use, and disease outbreaks such as EUS, all of which threaten biodiversity. Therefore, it is essential to focus on the cultivation of SIS, as they are rich in vitamin A and essential minerals (Thilsted et al., 1997). Incorporating SIS into polyculture systems alongside large carps can improve both household nutrition and income for low-income families. In terms of nutritional benefits, the cultivation of SIS is comparable to home gardening, which is widely encouraged as a strategy to address vitamin deficiencies, boost food production, and improve food availability for the underprivileged.

2 Materials And Methods

a. Study location

The present study was conducted from August to December in the hatchery Shade-II of the Department of Zoology and Applied Aquaculture, Barkatullah University.

b. Experimental design

The experiment was conducted in two treatments. In treatment-1, three major Indian carps, rohu- *Labeo rohita, catla- Labeo catla and mrigal- Cirrhinus mrigala* and three small fish species, such as *Systomus sarana, Pethia ticto and rasbora*- Rasbora daniconius were stocked. In treatment-2, only small fish species (*Systomus sarana, Pethia ticto and Rasbora daniconius*) were stocked.

Table 1 Layout of the experiment (fish species composition)

Species	TANK 1	TANK 2
Labeo rohita	8	
Labeo catla	8	
Cirrhinus mrigala	12	
Systomus sarana	10	20

Pethia ticto	10	20
Rasbora daniconius	12	20
TOTAL	60	60

3 TANK PREPARATION

All unwanted leaves and insects were eradicated from the tank. Tanks were cleaned and treated with potassium permanganate ($KMnO_4$). Later, the tank was fertilized with cow dung at fortnightly intervals.

1. Collection of fishes

The fingerlings of small fish species and IMCs were collected through netting from the pond in the department of Zoology and Applied Aquaculture, Barkatullah University, Bhopal. Fingerlings were brought to the experimental site through hundi.

2. Fry stocking

The fry and fingerlings were transferred into the hundi and released into the tank. The length and weight of all the fingerlings were measured to estimate initial stocking biomass and to adjust the initial feeding rate for the fish.

3. Feeding of fishes

Common agricultural by-products like fine rice bran and mustard oil cake were used as supplementary feed, mixed in equal proportions to form a dough. This feed was provided to the fish daily at a rate equivalent to 4% of their total body weight.

4. Fertilization

The tanks were fertilized with cow dung and were given at a 7-day interval throughout the culture period.

5. Growth sampling of fish

Fish were sampled fortnightly at every two weeks through netting from both T1 & T2. To assess the growth of the fish and adjust the feeding rate. The length of the fishes was measured by measuring scale and weight of the fishes were measured by using the RTB 200gm weighing machine. Fishes were sampled with dragnets of suitable mesh sizes. Fishes were handled carefully to avoid stress during sampling.

6. Water quality analysis

Water quality plays a vital role in fish growth. Key water quality parameters—including temperature (°C), pH, dissolved oxygen (DO), carbon dioxide, and alkalinity—were monitored on a weekly basis. Water samples were taken from both tanks (T1 and T2). Temperature was measured using a handheld mercury thermometer, pH was assessed using pH paper, and other parameters such as DO, carbon

dioxide, hardness, and alkalinity were determined using the titrimetric method, following the guidelines of APHA (1995).

7. **Survival Rate**

The survival rate of the fish was calculated by using the following formula:

Survival Rate (%) = No. Of fish harvested /No. of fish stocked

8. **Specific Growth Rate (SGR) (%)**

X 100 It is related to the increase in weight of the fish's body after a certain point in time. It is calculated as follows:

SGR = In (final weight in gm) – In (initial weight in gm) /Days of culture X 100

Fig.1: Tank 1 (IMCs with SIFs)

Fig.2: Tank 2 (Small fish species)

Fig.3: Tank treated with KMn0$_4$

Fig.4: Collection of fish

Species cultured

1. SIS

Fig.5: *Systomus sarana*

Fig.6: *Pethia ticto*

Fig.7: Rasbora daniconius

2. IMCs

Fig.8: Labeo rohita

Fig.9: Labeo catla

Fig.10: Cirrhinus mrigala

RESULTS

The overall mean values of each water quality parameter in both the tank (1&2) are presented in table 1 & 2.

Table 2 Physico-chemical parameters of Tank- 1

Parameters	August		September		October		November		December		Mean ± SD	Min- max
	12th	27th	11th	26th	11th	26th	10th	25th	10th	25th		
Temperature (^{0}C)	25	27	26	28	27	26	22	24	25	23	25.3±1.88	22-28
pH	6.9	6.8	7.0	7.3	7.4	7.8	7.6	7.7	7.5	7.2	7.32±0.34	6.8-7.8
Free CO2 (mg/l)	0.8	1.3	0.7	2.1	2.3	1.7	2.4	2.1	2.5	3.0	1.89±0.753	0.7-3
DO (mg/l)	6.4	6.6	7.0	6.9	7.3	7.4	7.1	7.5	7.3	7.2	7.07±0.352	6.4-7.5
Total Alkalinity (mg/l)	121	141	119.6	145.7	170.8	114.6	150.6	165.3	148.7	130.2	140.75±19.21	114.6-170.8
Total Hardness (mg/l)	114.6	136	123	154.3	147.1	99.7	161	134.8	128.8	138	133.73±18.35	99.7-161

Table 3 Physico-chemical parameters of Tank- 2

Parameters	August		September		October		November		December		Mean ± SD	Min-max
	12th	27th	11th	26th	11th	26th	10th	25th	10th	25th		
Temperature (^{0}C)	27	26	28	25	27	24	23	25	24	22	25.1±1.91	22-28
pH	6.8	7.0	6.9	7.1	7.3	7.7	7.5	7.6	7.4	7.3	7.26±0.302	6.8-7.7

Free CO_2 (mg/l)	0.9	1.5	0.8	2.1	2.5	1.8	3	2.2	2.7	2.3	1.98±0.731	0.8-3
DO (mg/l)	6.4	6.8	7.1	7.7	7.3	6.6	7.5	7.2	7.4	7.3	7.13±0.411	6.4-7.7
Total alkalinity (mg/l)	127.1	134	147.3	157.3	164	168.4	119.2	150.7	141	144	145.3±15.70	119.2-168.4
Total Hardness(mg/l)	115	128.1	94.6	145.4	162.5	136.5	140.7	151	134	155.2	136.3±20.07	94.6-162.5

The water temperature in both tanks (T1 and T2) was fairly consistent. The average temperature in T1 was 25.3 ± 1.88°C, ranging from 22 to 28°C, while in T2 it was 25.1 ± 1.91°C within the same range. pH levels in both tanks showed fluctuations, ranging from 6.8 to 7.8 in T1 and 6.8 to 7.7 in T2. The lowest pH value (6.8) was recorded on August 12th in T2, and the highest (7.8) was noted on October 26th in T1. Free CO_2 levels in T1 reached up to 3 mg/L with a mean of 1.89 ± 0.753 (range: 0.7–3), while in T2 the mean was significantly higher at 7.13 ± 0.411 (range: 6.4–7.7). The mean pH values were 7.32 ± 0.34 in T1 and 7.26 ± 0.302 in T2. Dissolved oxygen levels ranged between 6.4 and 7.5 mg/L in T1 (mean: 7.07 ± 0.352), and between 6.4 and 7.7 mg/L in T2 (mean: 7.13 ± 0.411). No significant differences were observed between the mean values across the tanks. Total alkalinity fluctuated throughout the experiment, with average values of 140.75 ± 19.21 mg/L (range: 114.6–170.8) in T1 and 145.3 ± 15.70 mg/L (range: 119.2–168.4) in T2. Total hardness ranged from 114.6 to 138 mg/L in T1 and 115 to 155.2 mg/L in T2, with mean values of 133.73 ± 18.35 and 136.3 ± 20.07, respectively.

Table 4 Showing observed average Length (cm) under both Tank (1&2)

Tank	Fish species	Initial average Length (cm)	Observed average Length (cm)										Final average Length (cm)
			August		September		October		November		December		
			12^{th}	27^{th}	11^{th}	26^{th}	11^{th}	26^{th}	10^{th}	25^{th}	10^{th}	25^{th}	
T-1	*Labeo rohita*,	9.2	9.97	10.2	10.08	10.31	11.43	11.5	11.66	11.7	11.8	12.4	11.10
	Labeo catla	8.8	9.90	10.3	10.7	11	11.04	11.4	11.6	11.75	11.81	12	11.15
	Cirrhinus mrigala	10	10.35	10.58	10.9	11.2	11.33	11.67	11.8	12.8	13.3	13.5	11.74
	Systomus sarana	5.9	6.81	7.34	8.7	9.4	9.7	9.91	10.4	10.7	10.9	11	9.48

	Pethia ticto	6.2	6.70	7.16	8.5	8.8	9.4	9.61	9.7	9.8	10	10.9	9.05
	Rasbora daniconius	6.68	7.53	8.8	9.5	10.1	10.6	11.2	11.6	11.87	12.3	12.5	10.6
T-2	*Systomus sarana*	6	6.87	7.8	8.5	9.6	9.8	10	10.8	11.1	11.5	12	9.79
	Pethia ticto	6.5	7.6	8.3	8.45	9.4	9.7	10.2	10.51	10.6	10.9	11.4	9.70
	Rasbora daniconius	6.8	7.1	7.5	8.8	9.18	9.35	9.7	10.62	11.2	12.4	12.6	10.11

On the basis of the final growth attained by each species, it was observed that among all species, the highest growth was obtained from the mrigal. The final average weight of mrigal attained 13.47g in tank 1. Catla reached an average weight of 12.58g, and rohu is 11.73g. The average higher growth of small fish species (*Systomus sarana, Pethia ticto and Rasbora daniconius*) was 8.97g, 8.98g and 9.41g in tank-2, where no IMCs were kept. The average weight of *Systomus sarana, Pethia ticto and Rasbora daniconius* in tank-1 is 8.8g, 8.73g and 9.29g. There was not much significant difference in the survival rates of both the tanks, which were 82.35% in tank-1 and 86.6% in tank-2.

Table 5 Showing Survival Rate of both Tanks (1&2)

Tank	Fish species	Survival Rate (%)	
		Species wise	Average
T-1	*Labeo rohita,*	80	82.35
	Labeo catla	87.5	
	Cirrhinus mrigala	83.3	
	Systomus sarana	80	
	Pethia ticto	80	
	Rasbora daniconius	83.3	
T-2	*Systomus sarana*	85	86.6
	Pethia ticto	85	
	Rasbora daniconius	90	

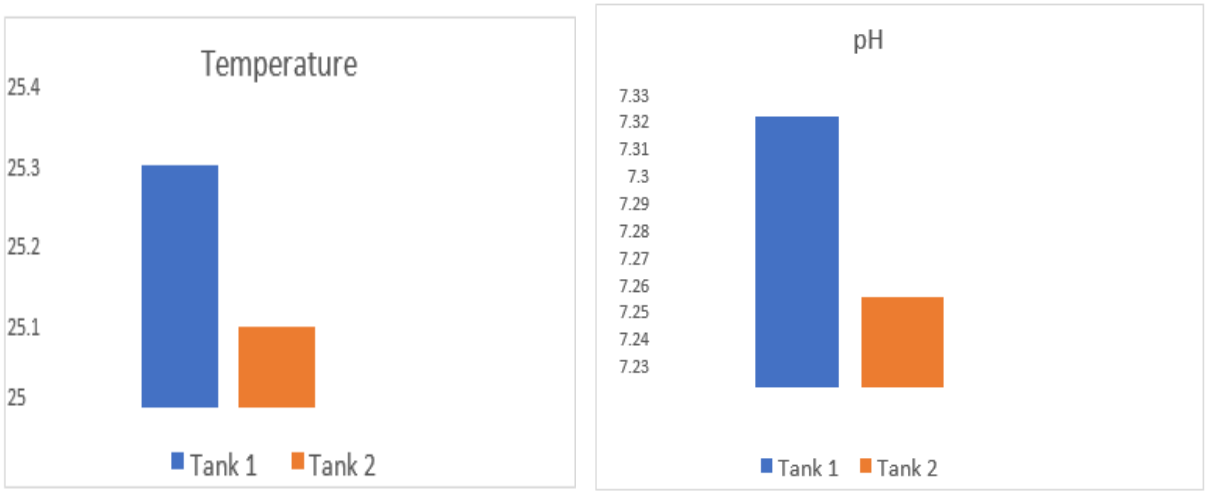

Fig 12: Graph showing variation in CO2 in tank (1&2)

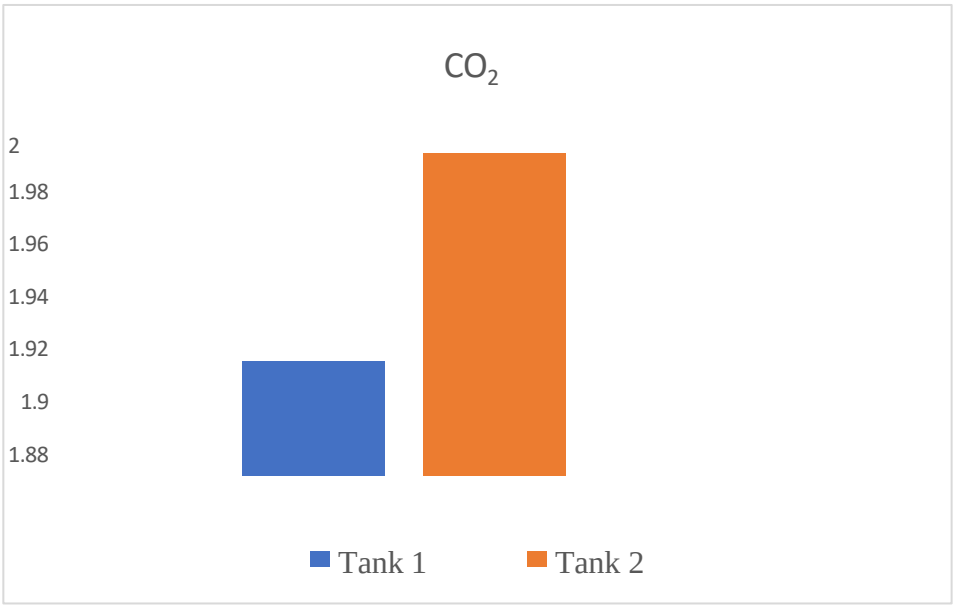

Fig 13: Graph showing variation in DO in tank (1&2)

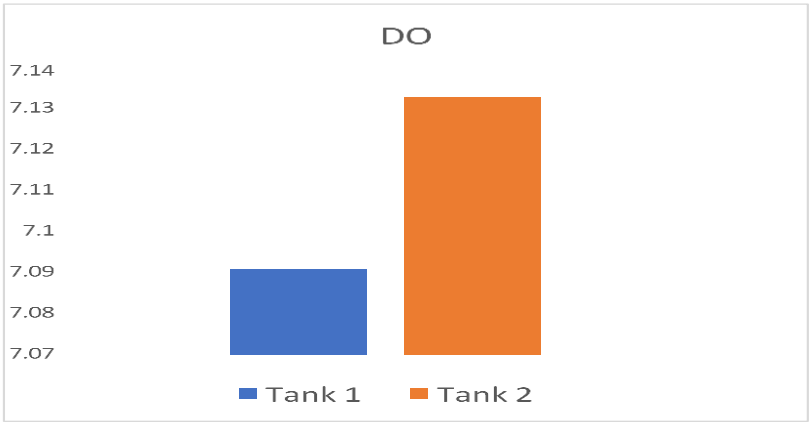

Fig 14: Graph showing variation in pH in tank (1&2)

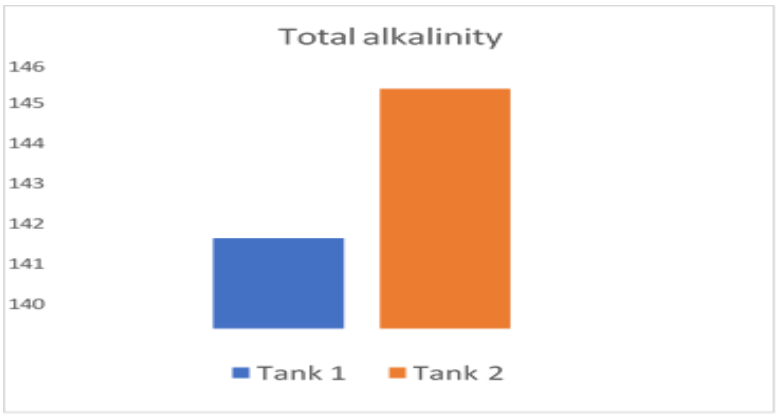

Fig 15: Graph showing variation in Total alkalinity in tank (1&2)

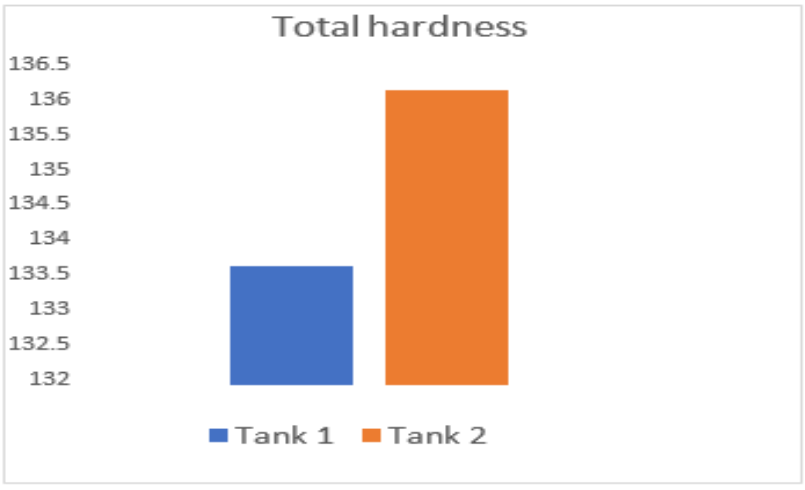

Fig 16: showing variation in Total hardness in tank (1&2)

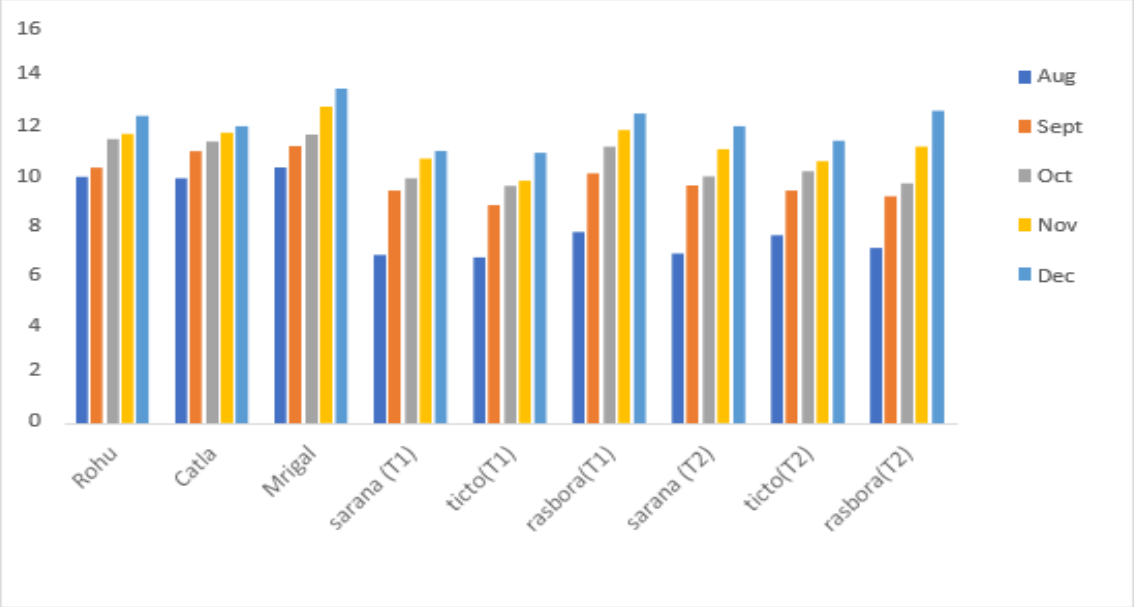

Fig 17: Graph showing variation in length of fish in tank (1&2)

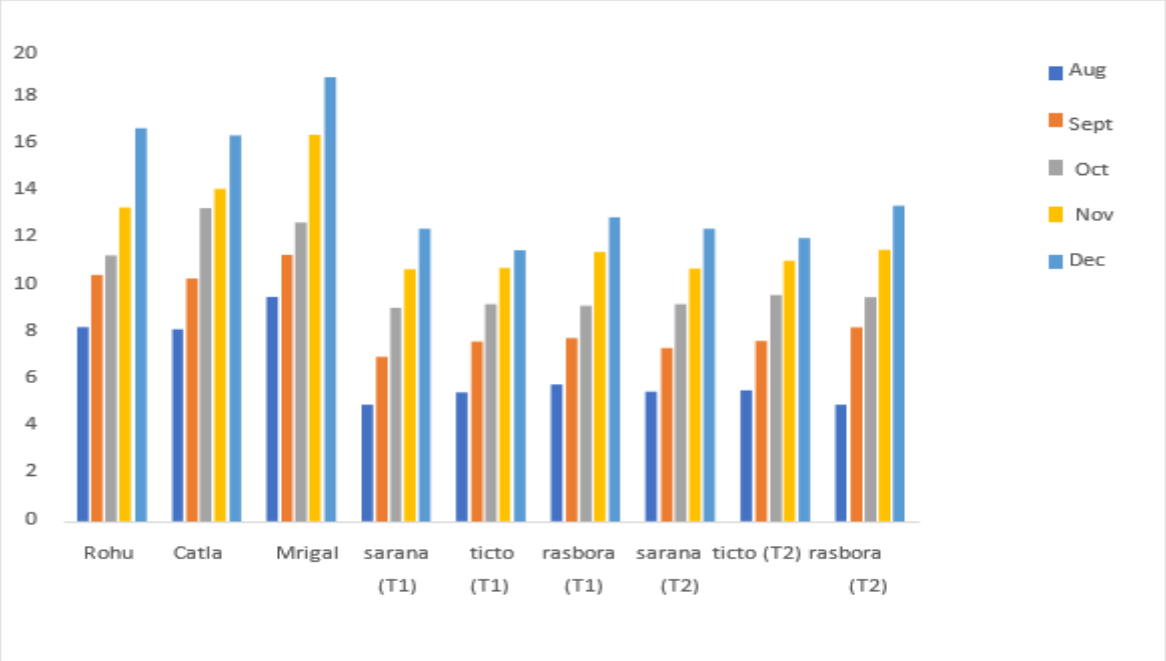

Fig 18: Graph showing variation in weight of fish in tank (1&2)

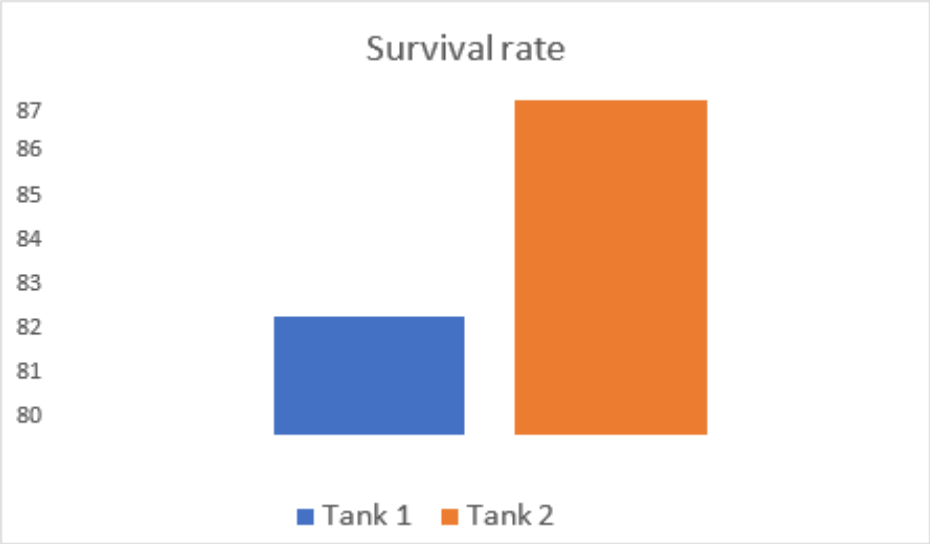

Fig 19: Graph showing survival rate of fish in tank (1&2)

4 Discussion

Small fish species have traditionally played a vital role in meeting the nutritional needs of rural poor communities. However, these species are now under threat of extinction due to overfishing and habitat degradation. Integrating small fish with carp in polyculture systems could provide both commercial benefits and support conservation efforts. Therefore, this study discusses and compares various water quality parameters and growth data observed during the experiment. Overall, water quality remained within acceptable limits across all treatments, with no abrupt changes detected in any parameter. Among these, water temperature is a key environmental factor that affects the physical, chemical, and biological dynamics of aquatic systems. In this study, temperatures ranged from 22°C to 28°C in both tanks. The highest temperatures were observed in August, while the lowest were recorded in November and December. Previous studies have reported similar findings, such as Hasan et al. (2002), who observed a temperature range of 24.4–33.0°C in ponds at the BAU campus in Mymensingh, Bangladesh. Similarly, Rahman et al. (1992) found that water temperatures between 25.5°C and 30.0°C conditions favorable for fish culture.

pH is another critical parameter in aquaculture. An acidic pH can negatively affect fish growth, metabolism, and other physiological functions (Swingle, 1967). An optimal pH range for pond fish culture lies between 6.5 and 9.0, while levels above 9.5 are unsuitable due to the lack of free CO_2. In the current study, pH levels ranged from 6.8 to 7.8 in Tank 1 (T1) and 6.8 to 7.7 in Tank 2 (T2), falling within the ideal range for fish farming. In comparison, Mollah and Haque (1978) recorded pH levels between 5.66 and 7.44 in ponds at the BAU campus, and Kohinoor et al. (1998) reported pH values ranging from 7.18 to 7.24 in research ponds at the same location. Dissolved oxygen (DO) levels in this study ranged from 6.4 to 7.5 mg/L in T1 and 6.4 to 7.7 mg/L in T2, with average values of 7.07 ± 0.352

mg/L and 7.13 ± 0.411 mg/L, respectively. The highest DO concentrations were recorded in November, and the lowest in August. Throughout the study, fish showed no signs of oxygen stress, indicating that DO levels were adequate. In contrast, Wahab et al. (1995) reported DO levels between 2.0 and 7.2 mg/L during experiments at the BAU campus.

Total hardness in Tank 1 ranged from 114.6 to 138 mg/L, while in Tank 2 it ranged from 115 to 155.2 mg/L. The average hardness values were 133.73 ± 18.35 mg/L in T1 and 136.3 ± 20.07 mg/L in T2. The highest hardness levels were recorded in November, and the lowest in September. According to Wahab et al. (1995), total hardness typically falls within the range of 45–108 mg/L. Swingle (1997) proposed that 50.5 mg/L (as $CaCO_3$) serves as the dividing line between soft and hard water. He further noted that waters with hardness above 15 mg/L are generally sufficient for fish farming without the need for lime, whereas those below 12 mg/L require liming to improve fish production.

In this study, the highest weight gains among small fish species *Systomus sarana, Pethia ticto, and Rasbora daniconius* were observed in Tank 2, where Indian major carps (IMCs) such as Catla, Rohu, and Mrigal were not stocked. In contrast, the lowest weight gains occurred in Tank 1, where small fish were cultured alongside IMCs. This suggests that competition for food occurred, especially between the small fish and Catla and Rohu. As noted by Chandra (1986), Catla and Rohu primarily feed on plankton, while Mrigal is an omnivore and bottom feeder. Weight gain for *S. sarana, P. ticto, and R. daniconius* was recorded as 12.5g, 11.6g, and 13g in Tank 1, and 12.5g, 12.1g, and 13.5g in Tank 2, respectively. For IMCs (Labeo rohita, Labeo catla, and Cirrhinus mrigala), the weight gains were 16.8g, 16.5g, and 19g. Length gain for the same small fish species was 11cm, 10.9cm, and 12.5cm in Tank 1, and 12cm, 11.4cm, and 12.6cm in Tank 2. Corresponding length gains for the IMCs were 12.84cm, 12cm, and 13.5cm.

Survival rates were 82.35% in Tank 1 and 86.6% in Tank 2, with no statistically significant differences between the treatments. The study found that lower stocking densities led to relatively higher survival rates. Hasan et al. (2002) reported similar results, with survival rates ranging from 82.67% to 88.00% in ponds at the BAU campus in Mymensingh, Bangladesh.

5 Conclusion

The findings of this study clearly demonstrate that incorporating small fish species into carp polyculture systems is a practical and effective approach for achieving satisfactory production alongside Indian major carps. The inclusion of small fish species can enhance overall fish growth, and their presence did not significantly hinder the growth performance of *Rohu, Catla, and Mrigal*. These small fish, *Systomus sarana, Pethia ticto, and Rasbora daniconius* play a crucial role in providing essential nutrition, food security, and additional income, especially for the poor and marginalized communities. Their integration into polyculture systems contributes valuable micronutrients, including vitamin A, thereby supporting better household nutrition. Consequently, efforts to promote and conserve such fish production systems should be prioritized. Furthermore, small and shallow water bodies hold great potential and should be effectively utilized for the cultivation of small fish species.

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Effect of Greenlight on the Growth Enhancement of Indian Major Carp in Bhopal, Madhya Pradesh

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Abstract

The present study investigates the effect of green LED light exposure on the growth enhancement of Indian Major Carp (*Labeo rohita*) under controlled laboratory conditions. A 100-day experimental trial was conducted from September to November 2023 at the Department of Zoology and Applied Aquaculture, Barkatullah University, Bhopal (23.19894°N, 77.45225°E). Juvenile Labeo rohita were stocked in two fiber-reinforced plastic (FRP) tanks: one exposed to green LED light (520 nm) and another subjected to a standard photoperiod. Physico-chemical parameters such as temperature, dissolved oxygen (DO), pH, carbon dioxide (CO_2), and alkalinity were monitored weekly and remained within suitable ranges for carp culture. Fish were fed commercial floating pellets to satiation twice daily, and water was continuously aerated. Growth performance was assessed through regular measurement of fish length and weight. Initial length and weight of fish were 4 cm and 0.6 g, respectively. By the end of the experiment, fish reared under green light conditions exhibited slightly higher growth (final weight 1.25 g; length 6.05 cm) compared to those in the standard photoperiod tank (final weight 1.19 g; length 5.9 cm). Survival rates were also favorable, recorded at 92.5% in the green light tank and 88% in the control tank. The study indicates that green LED lighting can positively influence the growth and survival of Labeo rohita, making it a promising strategy for enhancing aquaculture productivity in controlled environments.

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1 Introduction

Aquaculture, often considered the aquatic equivalent of agriculture, has experienced significant growth in recent decades. Today, it produces nearly as many fish and shellfish as capture fisheries (FAO, 2014). As natural fisheries face increasing pressure, aquaculture is emerging as the primary strategy for enhancing food production from aquatic ecosystems. However, its expansion poses biodiversity risks due to resource consumption such as land (or space), water, seed, and feed, and the transformation of these into products desired by society. This process also leads to the release of various byproducts into the environment, including greenhouse gases, uneaten feed, faeces, urine, chemical treatments, and the spread of parasites, pathogens, and non-native species (Max Troell, 2017). Aquaculture involves the breeding and cultivation of aquatic organisms such as aquatic plants, fish, and shellfish (e.g., oysters, mussels, clams, shrimp, crabs, and crawfish) in controlled or semi-controlled settings. It serves diverse purposes: from restocking natural water bodies for recreational or commercial fishing, conserving endangered species, to producing marketable aquatic crops in ponds, rivers, or coastal areas. In essence, aquaculture mirrors agriculture, with water serving as the medium instead of soil. Depending on the species, cultivation may occur in freshwater, brackish, or marine environments.

Freshwater fish typically grow best at temperatures between 25 and 30°C. Among the Indian major carps, Rohu (*Labeo rohita*) is particularly significant in carp polyculture systems (Nadia Nazish and Abdul Mateen, 2010). This species is eurythermal, although it does not perform well at temperatures below 14°C. Under standard farming conditions, Rohu is a fast-growing fish that can reach lengths of 35–45 cm and weights of 700–800 grams within a year. Similarly, Mrigal is also eurythermal, tolerating temperatures down to 14°C. As a bottom feeder, Mrigal helps maintain environmental balance in polyculture systems by consuming organic debris. When natural food resources become scarce, supplementary feeding becomes necessary, with energy rather than protein often being the limiting nutrient. Feed costs typically represent 40–60% of the total expenses in freshwater fish farming. The use of artificial feed, particularly in fertilized ponds, can significantly improve growth and production rates compared to fertilization alone (Diana et al., 1994). However, both high and low stocking densities can impede growth, with high densities also causing undesirable changes such as darker skin coloration in fish (Marandi et al., 2018; Wallace et al., 1988; Zeng et al., 2010).

Light is a critical environmental factor that significantly influences fish development. It serves as a natural signal for seasonal biological activities, playing a key role in regulating circadian rhythms as well as various physiological and behavioral functions. Light characteristics such as spectrum, intensity, and photoperiod vary greatly across aquatic environments, making it a highly dynamic element in aquaculture settings. Among these, the spectral composition of light is especially important for fish biology. Light-emitting diodes (LEDs) are increasingly being adopted in aquaculture due to their efficiency and ability to emit narrow light bandwidths. This allows for spectrum customization to suit the specific visual and physiological sensitivities of target fish species (Villamizar et al., 2009; Yeh et

al., 2014). Specific light wavelengths have been shown to enhance fish growth and bolster their innate immune responses. Furthermore, different wavelengths can influence the secretion of melanin-concentrating hormone (MCH) a key appetite-regulating hormone in the brain—thereby stimulating increased feeding activity in fish.

Carp farming is the most ancient form of aquaculture known globally, and today, carps make up approximately two-thirds of the total fish produced. Belonging to the family Cyprinidae, which includes carps and their relatives, this group is recognized as the largest family of freshwater fishes and, in fact, the largest vertebrate family overall. The term "Cyprinidae" originates from the Ancient Greek word for carp. In India, carps form the foundation of aquaculture. The three Indian major carps Catla (*Catla catla*), Rohu (*Labeo rohita),* and Mrigal (*Cirrhinus mrigala*)—along with three exotic species Silver carp, Grass carp, and Common carp account for over 85% of the country's aquaculture output.

Determining the mathematical relationship between fish length (total or standard) and weight is a fundamental aspect of applied fisheries science. Length–weight relationships are essential for estimating the weight of individual fish based on their length or for calculating biomass from length-frequency data (Froese, 1998; Koutrakis et al., 2003). These relationships are also useful for evaluating the growth pattern of fish—whether it follows an isometric (proportional) or allometric (disproportional) pattern (Le Cren, 1951; Ricker, 1975). Extensive studies on the length–weight relationship and growth dynamics of Indian major carps have been conducted by researchers including Jhingran (1952, 1957, 1959), Sinha (1972), Choudhary et al. (1982), Johal et al. (1992), Zafar et al. (1992), Ahmed et al. (1996), Jain (2000), and Saxena et al. (2009).The purpose of this study was to determine and compare the growth rate of the fishes cultured in green light and controlled tank and to investigate the effects of LEDs on the fish.

2 Materials and Methods

Study area and Duration

A 100-day experimental study was carried out from September to November 2023 at the Department of Zoology and Applied Aquaculture, located in Bhopal, Madhya Pradesh (coordinates: 23.19894°N, 77.45225°E).

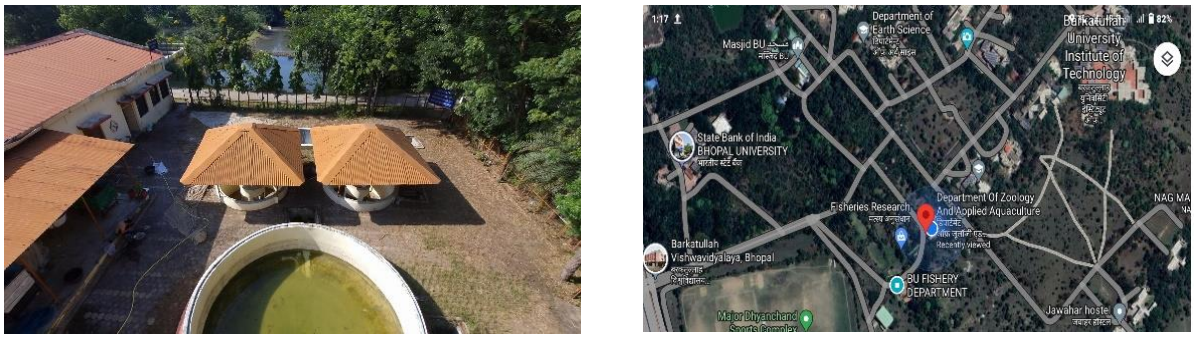


Fig 1 Study area and Duration

Tank Preparation

Firstly, the tanks were collected and cleaned with water. Further, the tanks were washed with KMnO4 and then washed again with water to rinse off the excess $KMnO_4$ from the tank in order to prevent any kind of contamination.

Fig 2: Roughly cleaning of tank

Fig 3: Tanks being washed

Fig 4: KMnO4 rinse

Experimental fishes and feeding

The fish seeds used in this study were sourced from a culture facility in Bhadhbada Fisheries Federation, Bhopal. They were transported to the laboratory of the Department of Zoology and Applied Aquaculture at Barkatullah University, Bhopal, using oxygen-filled live fish bags. Upon arrival, the fish were placed in tanks for further experimentation. The fish were fed commercially floating granules 2 times daily to satiation. Water was continuously aerated.

Experimental conditions

The fishes were poured into two different FRP tanks (2 m length × 1 m breadth × 0.75 cm height) one kept at the outside and the other in a dark room. The tank was given a greenlight (520nm) condition by placing 4 green LED bulbs above it and filled with water (~ L) with a temperature of 27-35°C. The photoperiod was given a 24-h light: dark photoperiod, respectively.

For the experiment, the fishes were transferred to a dark room and were exposed to green LED light bulbs

Fig 5: Controlled tank

Fig 6: Experimental tank with green LEDs.

Light exposure method

The LED light used in the experiment was purchased from a local shop in Baksewaniya, a district in Bhopal, Madhya Pradesh. The lights were bought in a quantity of four and were suspended above the tank for a more distributed spectrum. The lights were suspended 30 cm- 40 cm above the water surface of the tank.

Fig 7: Green LEDs used in the experiment

Sampling method

Growth evaluation of fish were randomly collected from each tank (10 days difference) for weight measurement using a digital balance. The total length of the fish was measured on a measuring board.

Fig 8: Digital weighing machine

Fig 9: Wooden measuring board

Physico-Chemical parameters

Water quality parameters- Physico-chemical parameters like water temperature, dissolved oxygen (mg/l), carbondioxide (mg/l), pH, and alkalinity (mg/l) of the tank were measured at a 7-day interval, and data were recorded on sampling dates.

pH

pH is a crucial parameter in aquaculture, reflecting the acidity or alkalinity of water or soil. Fish are unable to survive for extended periods in environments where the pH falls below 4 or rises above 11. The pH value is determined by the concentration of hydrogen ions (H^+) in the water. Measured on a scale from 1 to 14, a pH of 7 is considered neutral—neither acidic nor alkaline. Values below 7 indicate acidity, while those above 7 indicate alkalinity. For aquaculture practices, an ideal pH range generally lies between 6.5 and 9.0.

Temperature

Temperature significantly influences the growth and survival of aquatic organisms. It is especially critical for species like fish and shrimp, which are poikilothermic (cold-blooded), meaning their body temperature fluctuates with their environment. In artificial ponds with typical depths of 1 to 2 meters, the temperature difference between surface and bottom water is usually minimal.

Dissolved Oxygen (DO)

Dissolved oxygen is vital for the survival of fish and other aquatic organisms. The water's capacity to retain oxygen is largely temperature-dependent—warmer water holds less oxygen than cooler water. Most pond ecosystems can support oxygen concentrations between 10 to 12 mg/L. However, decomposition of organic matter—such as dead plants, animals, or waste—can lower oxygen levels. When dissolved oxygen drops below 6 mg/L, it may begin to negatively impact aquatic life.

Carbon Dioxide (CO_2)

Fish can generally tolerate carbon dioxide concentrations below 10 mg/L, although tolerance levels vary among species. CO_2 levels in water are influenced by the respiration and photosynthesis of aquatic organisms, the quality of incoming water, and the decomposition of organic materials, which can significantly elevate CO_2 in nutrient-rich environments.

Alkalinity

Alkalinity refers to the concentration of basic substances in water, primarily carbonates, bicarbonates, hydroxides, phosphates, and borates. Among these, carbonates and bicarbonates play the most significant roles in maintaining water quality. Alkalinity is a measure of water's ability to neutralize acids and is expressed in milligrams per liter (mg/L) or parts per million (ppm) as calcium carbonate ($CaCO_3$). It indicates the buffering capacity of water to resist changes in pH.

3 Growth Parameters

- The length gain (cm), weight gain (g), and survival rate were calculated using the following formulas:
- **Length gain (cm) =** Mean final length – Mean initial length
- **Weight gain (g) =** Mean final weight – Mean initial weight

- **Average body weight (ABW) =** Total weight of fishes / No. of fishes
- **Biomass =** ABW × No. of fishes stocked / 1000
- **Feed / Day =** Biomass × percentage of feed/100
- **(ADG) Average daily growth**

$$ADG = \frac{(\text{Final body weight} - \text{initial body weight})}{(\text{No. of feeding days})}$$

- **Feed Conversion ratio (FCR**)

$$FCR = \frac{\text{Feed Consumed by fishes}}{\text{Biomass Gained}}$$

- **Survival rate =** After completion of the experiment at 180th day, the number of total live fingerlings in the rearing pond was counted separately for calculation of the survival rate.

$$\text{Survival rate (\%)} = \frac{\text{Number of fish at harvest} \times 100}{\text{Total no. of fish stocked}}$$

Result

Physico-chemical parameters

Physico-chemical parameters like water temperature, dissolved oxygen (mg/l), carbon dioxide(mg/l), pH, and alkalinity(mg/l) of the tank were measured at 7-day intervals and data were recorded and observed.

Table 1 Water quality parameters for greenlight tank

Parameters	Aug		Sept		Oct		Nov		Dec	
	05	20	05	20	05	21	06	20	05	20
Temperature	25	26	29	28	27	26	22	21	23	21
D.O(ppm)	6.3	6.5	7.0	7.2	7.3	7.5	7.1	7.3	7.2	7.1
CO2	0.5	0.3	0.6	0.5	0.8	0.6	0.3	0.5	0.4	0.6
pH	7.0	6.9	7.4	8.0	7.5	7.9	7.4	7.6	7.3	7.2

Length-weight of the fishes

The length and weight of the fishes were taken in the time interval of around 7 days and further changed to 10 days in the winters. Initial length of the fishes were 4 cm and weight were 0.6gm respectively. The experiment took place in the month of September and lasted till December. A total of 10 readings were taken during the experiment in the interval of 4 months.

Table 2 Length and weight of Greenlight tank (*Labeo rohita*)

Month	Length	Weight
August	3.2	0.38
September	4	0.6
October	5.325	0.8675
November	5.85	1.1675
December	6.05	1.25

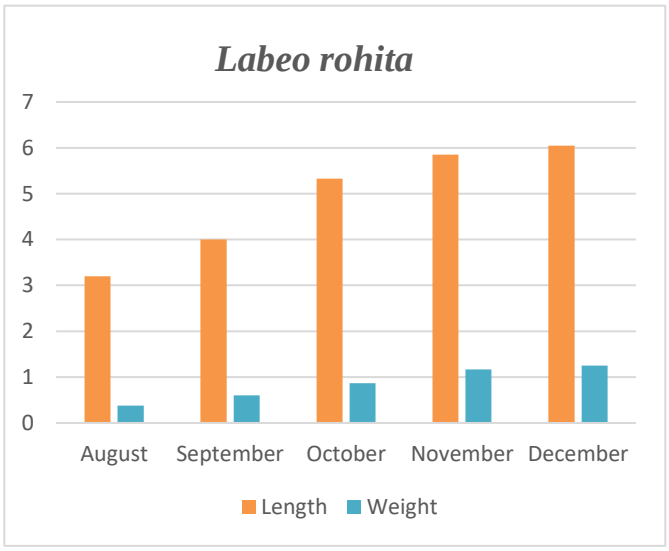


Table 3: Length and weight of photoperiod tank

Month	Length	Weight
August	3.2	0.38
September	3.75	0.54
October	4.525	0.7775
November	5.725	1.01
December	6	1.11

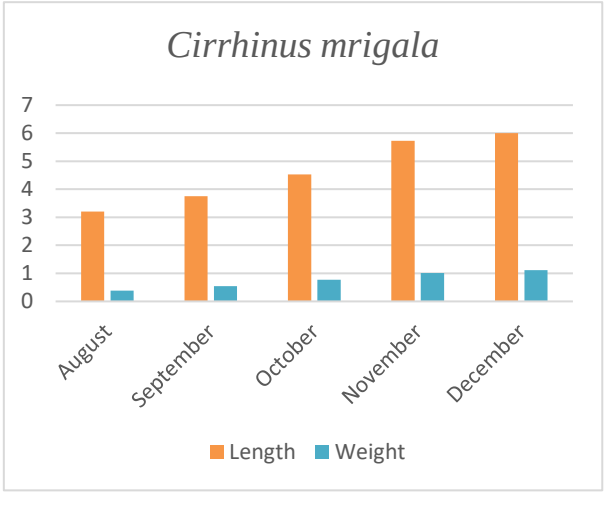
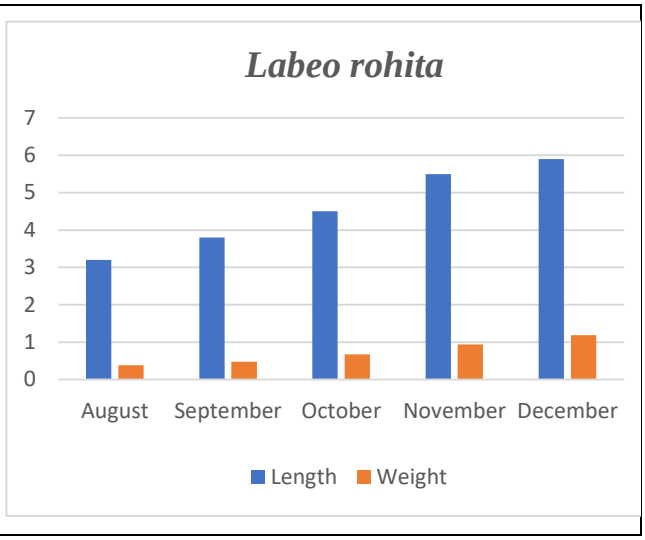
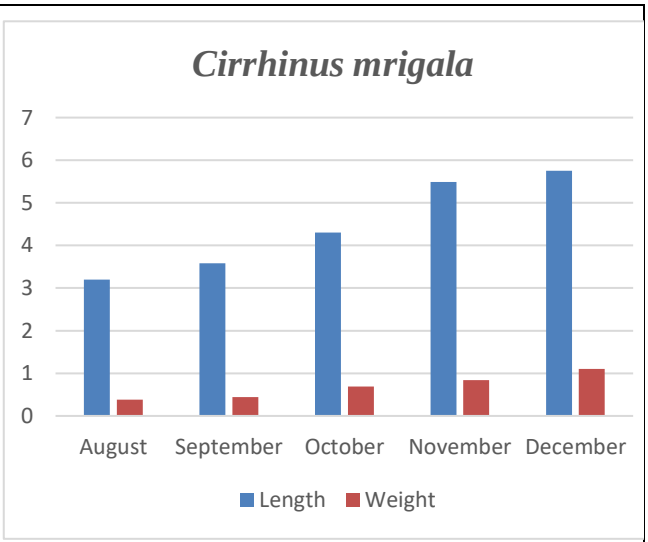


Table 4 Length and weight of photoperiod tank

Month	Length	Weight
August	3.2	0.38
September	3.8	0.48
October	4.5	0.67
November	5.5	0.94
December	5.9	1.19



Month	Length	Weight
August	3.2	0.38
September	3.58	0.44
October	4.3	0.69
November	5.49	0.84
December	5.75	1.1



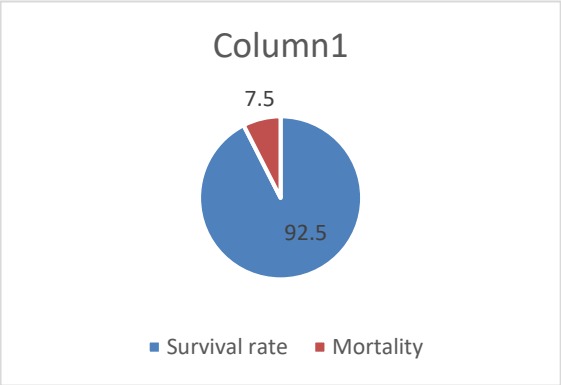
SURVIVAL RATE

Survival(%) = Number of species survived at end of experiment ×100

Number of species stocked

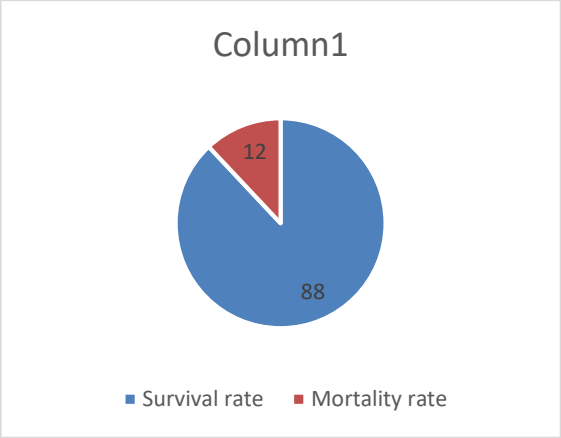
Greenlight tank

Survival rate	Mortality rate
92.5	7.5



Photoperiod tank

Survival rate	Mortality rate
88	12



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Study on ova structure of different gonadal stages of some Small Indigenous Fishes

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Abstract

The present study was conducted to examine the ova structure and fecundity patterns across different gonadal maturity stages in selected Small Indigenous Fish Species (SIFS). The investigation was carried out over a five-month period from August to December 2023 at the Laboratory of the Department of Zoology and Applied Aquaculture, Barkatullah University, Bhopal. Specimens were collected from multiple fish markets across Bhopal, including Kasturba, Vijay, Piplani, and Govindpura markets. Six species were selected for the study: *Rasbora daniconius, Amblypharyngodon mola, Gudusia chapra, Puntius ticto, Heteropneustes fossilis, and Clarias batrachus*. Total length, weight, fecundity, and ova diameter were recorded monthly. Ova diameter was measured using an ocular micrometer under a compound microscope, while fecundity was estimated using gravimetric methods by analyzing subsamples from different ovarian regions. Histological slides were prepared through alcohol dehydration, xylene clearing, eosin staining, and DPX mounting for structural observation of ova at various maturity stages. The study revealed significant interspecies and seasonal variations in fecundity and ova diameter. For instance, the maximum and minimum Fecundity for Rasbora daniconius are 13,912.29 in August and 3081 in September. For *Gudusia chapra*, the maximum and minimum Fecundity are 10,900 in September and 7013.83 in August. For *Puntius ticto*, the maximum and minimum Fecundity were found to be 23510.09 in August and 931 in November. For *Amblypharyngodon mola*, the maximum and minimum Fecundity were found to be 12147.07 in August and 1415.80 in September. For *Heteropneustes fossilis*, the maximum and minimum Fecundity were found to be

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19208.48 in September and 15174.77 in August, and for *Clarias batrachus*, the maximum and minimum Fecundity were found to be 18320 in August and 10564.2 in September. These findings contribute to a better understanding of reproductive biology in indigenous fish species, which is essential for their conservation, captive breeding programs, and sustainable aquaculture development.

Keywords: Ova structure, Gonadal stage, Fecundity, Small Indigenous Fishes.

1 Introduction

Small Indigenous Fish (SIF) species are those that typically reach a maximum length of about 25 cm at maturity. These species are rich in essential nutrients, including proteins, fatty acids, vitamins, and minerals. Notably, they are often consumed whole, including the head, bones, and eyes, which allows for the full utilization of available nutrients, particularly micronutrients.

In India, approximately 450 out of 765 documented native freshwater fish species are categorized as SIFs. The highest diversity of these species is found in the Northeast region, followed by the Western Ghats and Central India. SIFs play a crucial role in preventing malnutrition, especially due to protein and micronutrient deficiencies, thereby supporting both nutritional and livelihood security for rural populations. Species such as *Amblypharyngodon mola, Osteobrama cotio cotio, Esomus danricus,* and *Corica soborna* are known for their high content of vitamin A and other micronutrients. For instance, in Bangladesh, small fish like mola are the primary source of vitamin A and calcium for rural households.

Minnows, belonging to the family Cyprinidae, are a diverse group of small freshwater fish species. They typically have a laterally compressed body, a terminal mouth, and relatively large, shiny scales. Species such as *Amblypharyngodon mola, Gudusia chapra, Puntius ticto*, and *Rasbora daniconius* are examples of minnows. Catfish species like *Heteropneustes fossilis* and *Clarias batrachus* are characterized by cylindrical bodies and flattened ventral surfaces, which facilitate benthic feeding. They possess whisker-like barbels and are scaleless, distinguishing them from most other teleost fish.

Reproductive studies in fish often focus on gonadal development and maturation stages, which are critical for understanding spawning patterns and fecundity. Histological examination of gonads provides detailed insights into oocyte development, aiding in the determination of spawning periods and the estimation of annual fecundity. This information is essential for effective broodstock management and enhancing fish production.

Oocyte size distribution is a key parameter in assessing gonadal maturity. Ovaries are classified into three types based on oocyte development: synchronous, group synchronous, and asynchronous. Asynchronous ovaries, where oocytes at all stages of development are present, are often associated with species that have protracted spawning seasons and multiple spawning events.

Understanding the reproductive biology and fecundity of fish species is vital for sustainable aquaculture practices. This knowledge helps in optimizing breeding programs, improving fish production, and ensuring the conservation of aquatic biodiversity.

2 Methodology

1. Study Area

The study site was carried out at the Laboratory of the Department of Zoology and Applied Aquaculture of Barkatullah University, Bhopal, Madhya Pradesh.

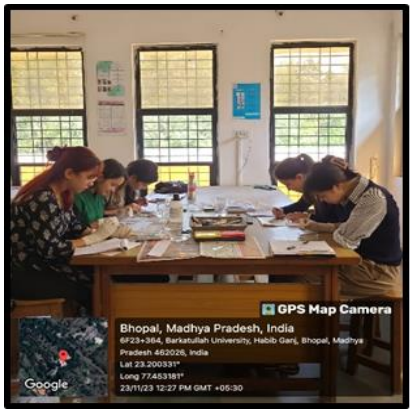


Fig 1: Laboratory at Department of Zoology and Applied Aquaculture, Barkatullah University, Bhopal, Madhya Pradesh.

2. Collection of specimens and sampling

The different varieties of species are collected from various markets in Bhopal, Madhya Pradesh, viz. Kasturba market, Vijay market, Piplani market, and Govindpura market for a period of 5 months starting from August to December 2023.

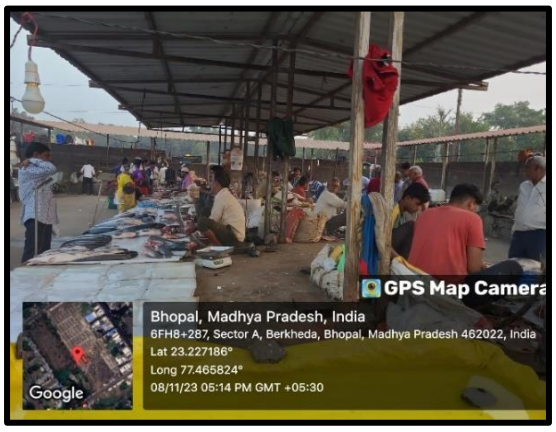


Fig 2: Vijay Market

Fig 3: Kasturba Market

Fig 4: Piplani Market

Fig 5: Govindpura Market

SPECIES NAME	**CLASSIFICATION**	
1. *Rasbora daniconius*	Phylum: Chordata Class: Actinopterygii Order: Cypriniformes Family: Cyprinidae Subfamily: Rasborinae Genus: Rasbora Species: R. daniconius	
2. *Puntius ticto*	Phylum- Chordata Class- Oesteichthyes Order- Cypriniformes Family- Cyprinidae Genus- *Puntius* Species- ticto	

3.*Gudusia chapra*	Phylum: Chordata Class: Actinopterygii Order: Clupeiformes Suborder: Clupeoidei Family: Clupeidae Subfamily: Alosinae Genus: *Gudusia* Species: *G. chapra*	
4.*Amblypharyngodon mola*	Phylum- Chordata Class-Oesteichthyes Order-Cypriniformes Family- Cyprinidae Genus- *Amblypharyngodon* Species-mola	
5. *Heteropneustes fossilis*	Phylum: Chordata Class: Actinopterygii Order: Siluriformes Superfamily: Siluroidea Family: Heteropneustidae Genus: *Heteropneustes* Species: *H. fossilis*	
6. *Clarias batrachus*	Phylum: Chordata Class: Actinopterygii Order: Siluriformes Superfamily: Siluroidea Family: Clariidae Genus: *Clarias* Species: *C. batrachus*	

3. Measurements of Length and Weight

The total length of the fish was measured by a measuring scale and the total body weight was measured by an electronic weighing machine.

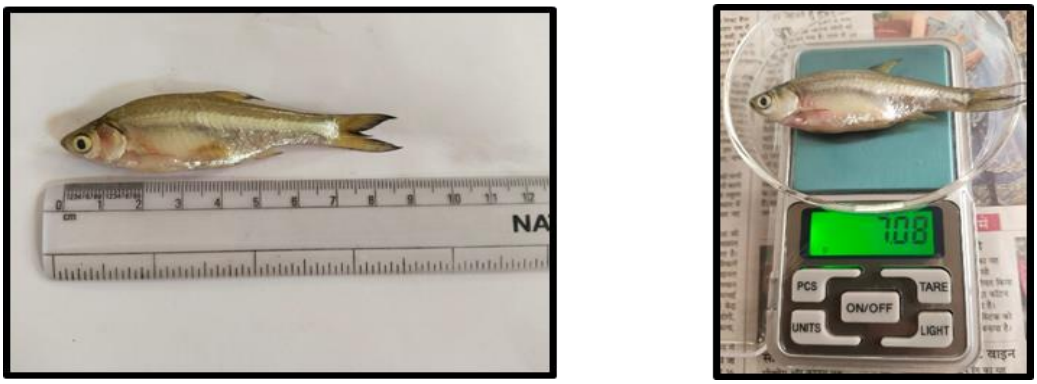


Fig 6: Length and Weight Measurement

4. Macroscopic determination of gonad maturity stages

The maturity stages were identified based on observable macroscopic features of the gonads. Specific characteristics such as color, overall condition, and morphometric measurements of the gonads were assessed. Additionally, the nature of the ova was carefully examined. The stage of gonadal development was determined using these external traits, including the size and appearance of the ovaries, following the I.C.E.S. scale described by Wood (1930).

5. Ova Diameter

To determine the diameter, a sample of ova from each maturity stages is taken in a Slide and is separated with the help of formalin solution and is recorded using an electronic compound microscope with the help of an Ocular micrometer

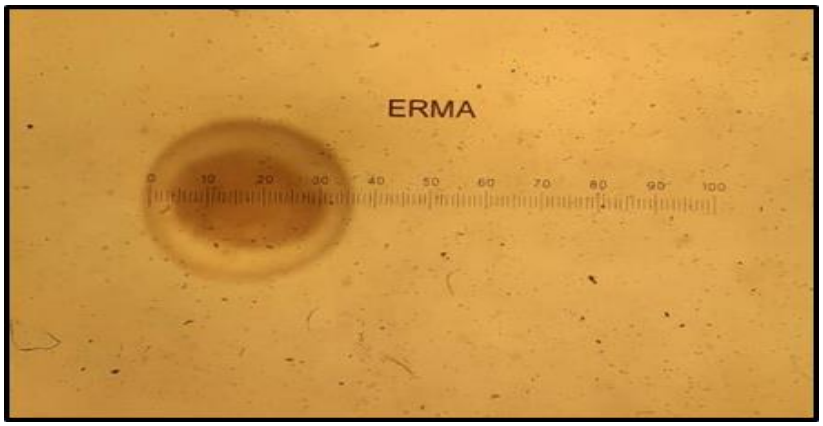


Fig 7: Figure showing the measurement of ova diameter

6. Fecundity

Fecundity was estimated by counting the number of mature eggs present in a known weight of fully mature or ripe ovaries. Subsamples were taken from the anterior, middle, and posterior sections of both

ovaries. These subsamples were evenly spread on a counting slide using a few drops of water, and the mature eggs were counted. The average number of eggs from the three sections was then used to calculate fecundity using the following formula:

$F = n \times G / g$

where F is fecundity, n is the number of eggs in the subsample, G is the total weight of the ovary, and g is the weight of the subsample.

Here,

F = Fecundity, n = Number of eggs in sub-sample, G = Weight of the ovary (gm),

g = Weight of the sub-sample (g)

7. Slides Preparation

For the structure of ova, ovaries of each maturity stage are preserved in permanent glass slides in alcohol for 24 hours.

- The ovaries are dehydrated with the help of a concentration of alcohol (30%, 50%, 70%, 90%) for 1 minute each.
- Xylene was applied to the slides as a clearing agent for 2 seconds.
- Staining was also done by using eosin as the required stain solution for 30 seconds.
- Again, it is dehydrated by using reverse osmosis concentrations of alcohol- 90%, 70%, 50%, 30% for 30 seconds each.
- Xylene is applied again for 2 seconds.
- Mounting is done with DPX, and placed on the slide is placed under the cover slip.
- Then the slides containing the ova are subjected for microscope observation.

Fig 8: Preservation of ova

Fig 9: Chemicals used for preparing slide preparation

3 Results and Discussion

Table 1: Monthly Variations of Length and Weight during gonadal development

Fish Species		August	September	October	November	December
Rasbora daniconius	TL	8.3116667	8.05	8.47	8.6	8.3579167
	TW	5.550556	4.9475	6.212	6.825	5.883764
Amblypharyngodon mola	TL	9.0333333	-	-	9.6285714	9.3309524
	TW	7.7266667	-	-	9.5314286	8.6290476
Gudusia chapra	TL	12.225	16.043333	12.766667	11.905714	13.235179
	TW	20.8	20.8	24.106667	16.75	20.614167
Puntius ticto	TL	11.6667	11.025	-	-	11.34585
	TW	25.2467	20.775	-	-	23.01085
Heteropneustes fossilis	TL	20.45	21.7	-	-	-
	TW	54.999	70.642	-	-	-

Clarias batrachus	TL	-	23.04	23.975	-	-
	TW	-	196.82	173.0725	-	-

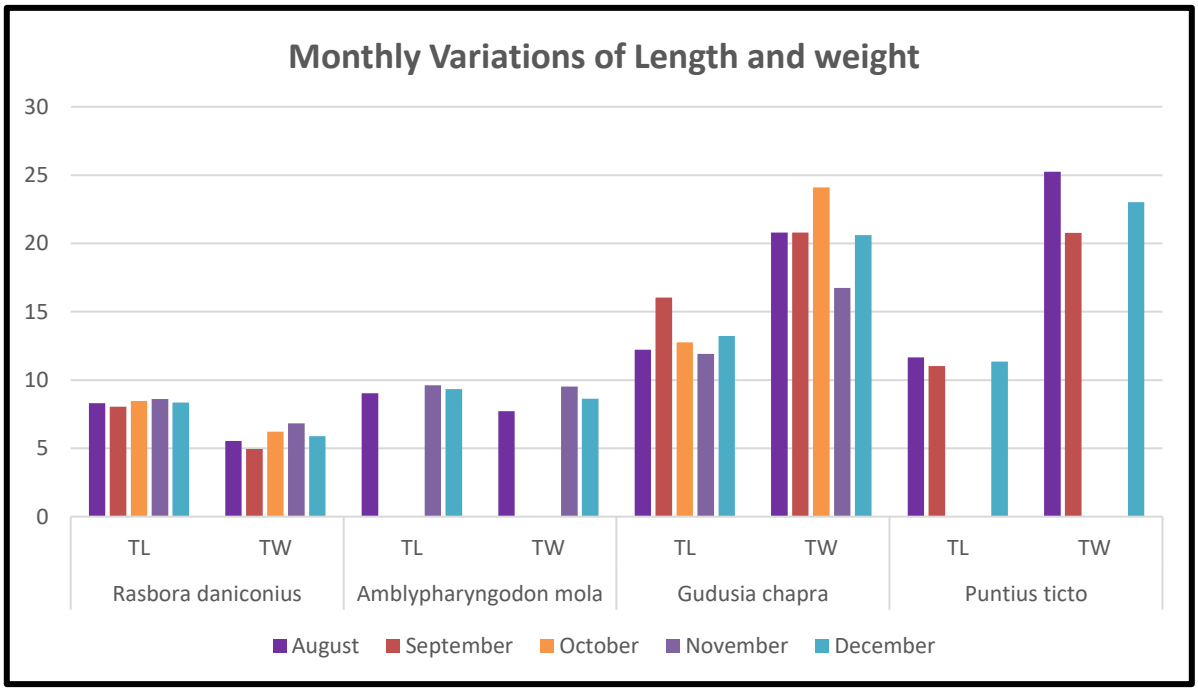


Fig 10: Monthly variations of average Length and Weight

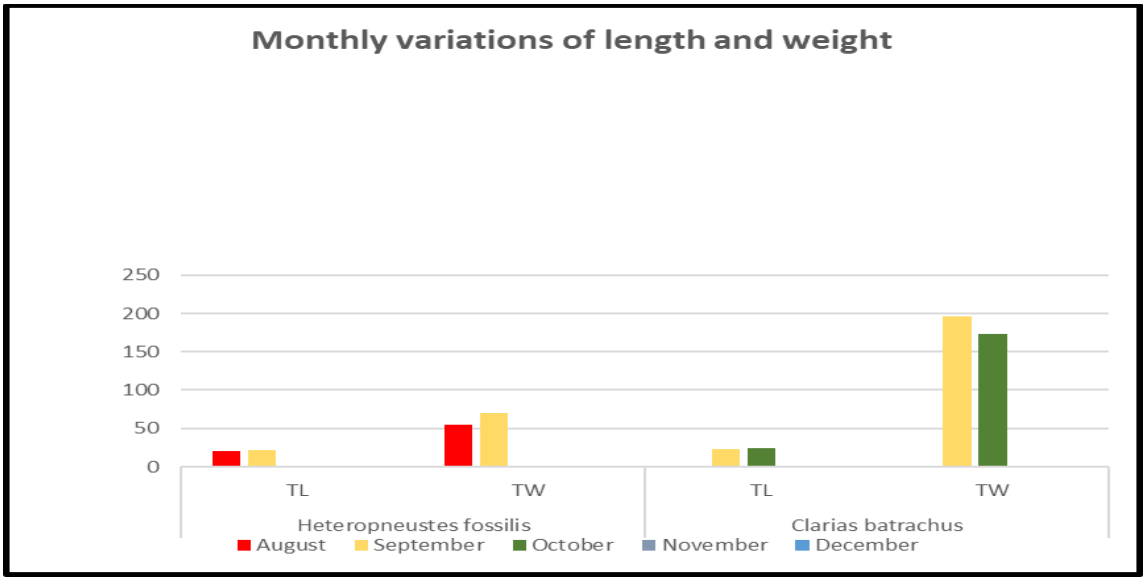


Fig 11: Monthly Variations of average Length and Weight

In Table 1, monthly variations of fish samples for length and weight were observed for a period of 5 months, i.e., from August to December. The results showed that the maximum and minimum total length for *Rasbora daniconius* is 8.6 cm in November and 8.0 cm in September and the maximum and minimum total weight is 6.82 g in November and 4.9 g in September.

The results showed that the maximum and minimum total length for *Amblypharyngodon mola* is 9.62 cm in November and 9 cm in August, and the maximum and minimum total weight is 9.53 g in November and 7.7 g in August. And the maximum and minimum total length for Gudusia chapra is 16.04 cm in September and 11.9 cm in August, and the maximum and minimum total weight is 24.1 g in October and 16.75 g in November.

The maximum and minimum total length for *Puntius ticto* is 11.6 cm in August and 11.0 cm in September, and the maximum and minimum total weight is 25.24 gm in August and 20.7 gm in September respectively and the maximum and minimum total length for *Heteropneustes fossilis* is 21.7 cm in September and 20.45 cm in August, and the maximum and minimum total weight is 70.6 gm in September and 54.99 gm in August.

The maximum and minimum total length for *Clarias batrachus* is 23.97 cm in October and 23.04 cm in September, and the maximum and minimum total weight is 196.82 g in September and 173.07 g in October.

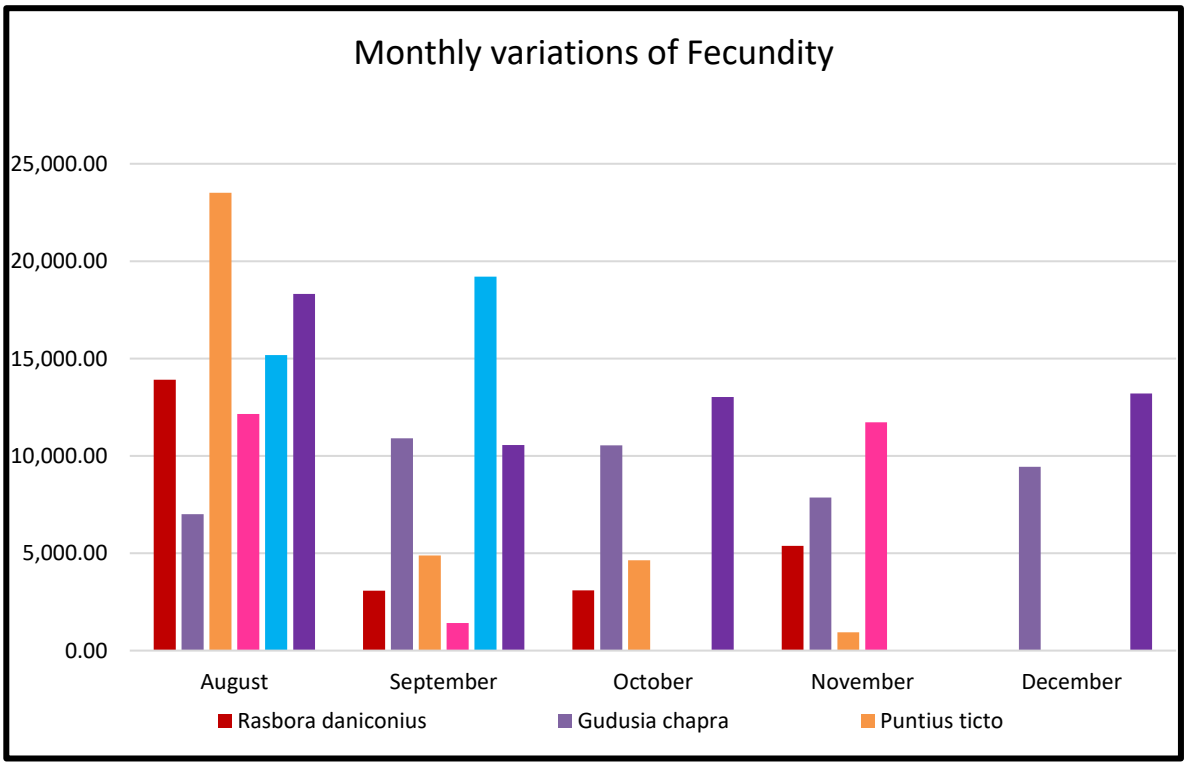


Fig 12: Monthly variations of average Fecundity

The Average Total Length and Weight of each species were arranged for each individual month and plotted against each other to understand the monthly variations (Fig 10 and 11).

Months	***Rasbora daniconius***	***Gudusia chapra***	***Puntius ticto***	***Amblypharyngodon mola***	***Heteropneustes fossilis***	***Clarias batrachus***
August	13,912.29	7,013.83	**23510.09**	12147.07	15174.77	**18320**
September	3081.431	**10900.07**	4,892.68	**1,415.80**	19208.48	10564.2
October	3092.556	**10,542.41**	**4640.65**		-	**13029.02**
November	5371	7858.667	**932**	11716.48	-	
December	-	**9433**	-	-	-	**13200**

Table 2: Monthly variations of Fecundity during gonadal development

From the above readings, Table 2 and Fig. 12, the maximum and minimum Fecundity for *Rasbora daniconius* are 13,912.29 in August and 3081 in September. For *Gudusia chapra*, the maximum and minimum Fecundity are 10,900 in September and 7013.83 in August. For *Puntius ticto*, the maximum and minimum Fecundity were found to be 23510.09 in August and 931 in November. For *Amblypharyngodon mola*, the maximum and minimum Fecundity were found to be 12147.07 in August and 1415.80 in September. For *Heteropneustes fossilis*, the maximum and minimum Fecundity were found to be 19208.48 in September and 15174.77 in August, and for *Clarias batrachus*, the maximum and minimum Fecundity were found to be 18320 in August and 10564.2 in September. The average fecundity values were plotted against each month to understand the monthly variations (Fig. 12).

Table 3: Monthly variations of Ova Diameter

Months	***Rasbora daniconius***	***Gudusia chapra***	***Puntius ticto***	***Amblypharyngodon mola***	***Heteropneustes fossilis***	***Clarias batrachus***
August	0.894	0.51	**0.99**	0.56	1.1625	**0.645**

September	0.945	**0.47**	1.075	**0.63125**	1.2	1.14
October	1.008	**0.39**	**0.97**	**0.75**	-	**1.2975**
November	0.953	0.47	**1**	0.754	-	**1.22**
December	-	**0.35**	-	-	-	-

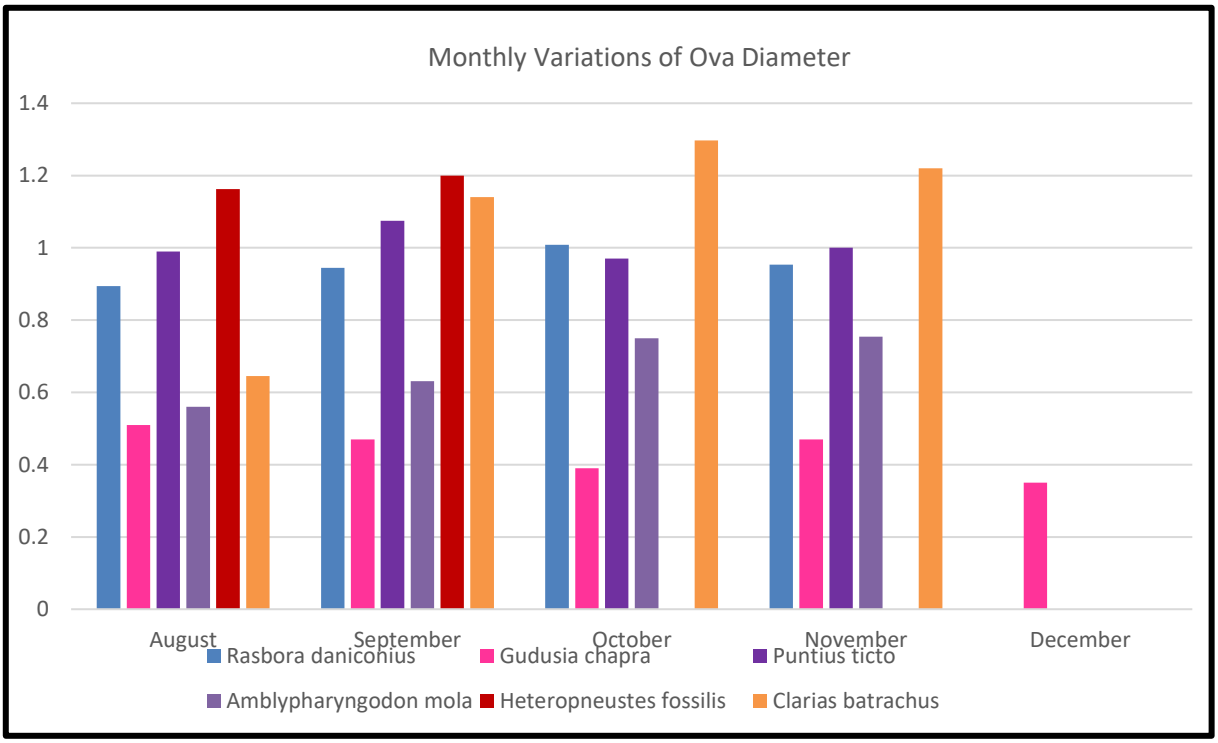


Fig 13: Monthly variations of Ova diameter

For *Rasbora daniconius*, the maximum and minimum ova diameter is 1.008 in October and 0.894 in August. For *Gudusia chapra*, the maximum and minimum ova diameter are 0.51 in August and 0.35 in December. For *Puntius ticto*, the maximum and minimum ova diameters are 1.075 in September and 0.97 in October. For *Amblypharyngodon mola*, the maximum and minimum ova diameters are 0.754 in November and 0.56 in August. For *Heteropneustes fossilis*, the maximum and minimum ova diameters

are 1.2 in September and 1.16 in August. For *Clarias batrachus*, the maximum and minimum ova diameter is 1.2975 in October and 0.645 in August.

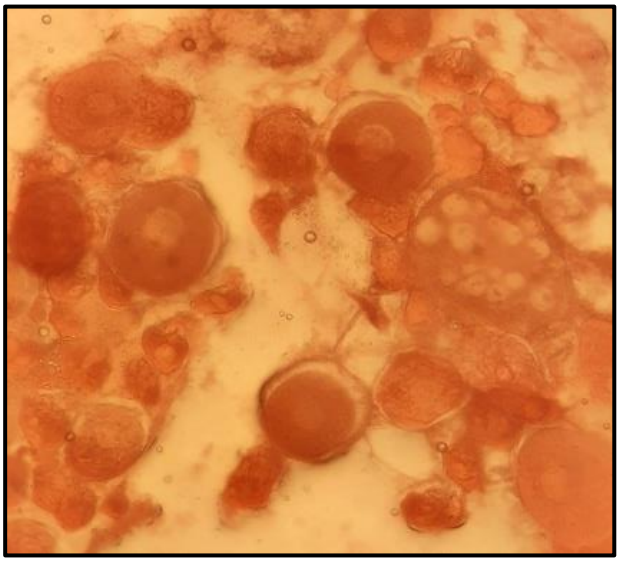


Fig 15*: Puntius ticto*

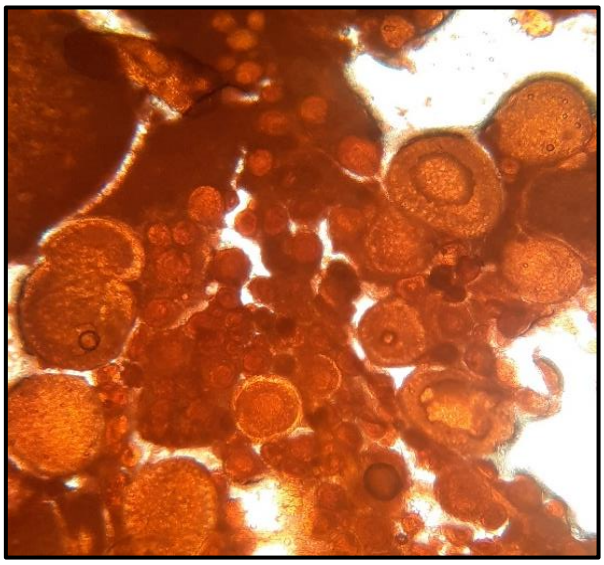


Fig 14*: Rasbora daniconius*

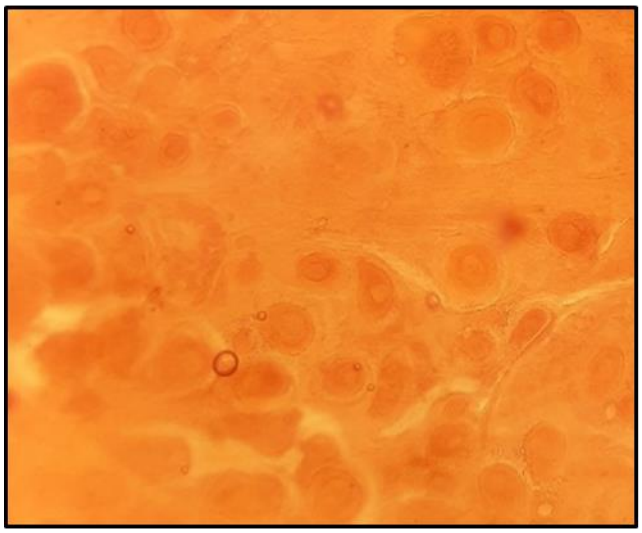


Fig 17: *Gudusia chapra*

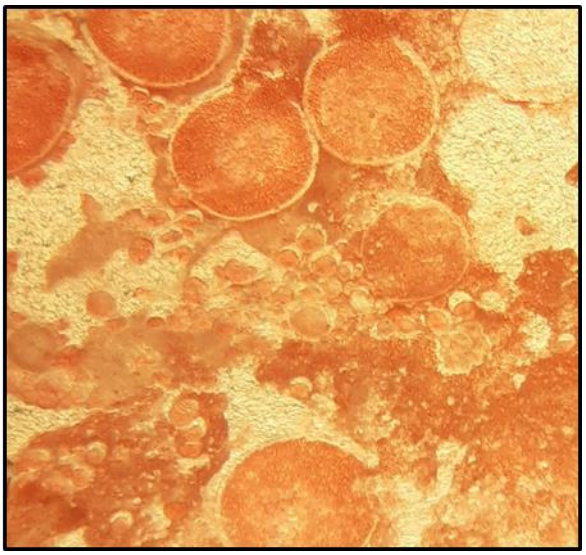
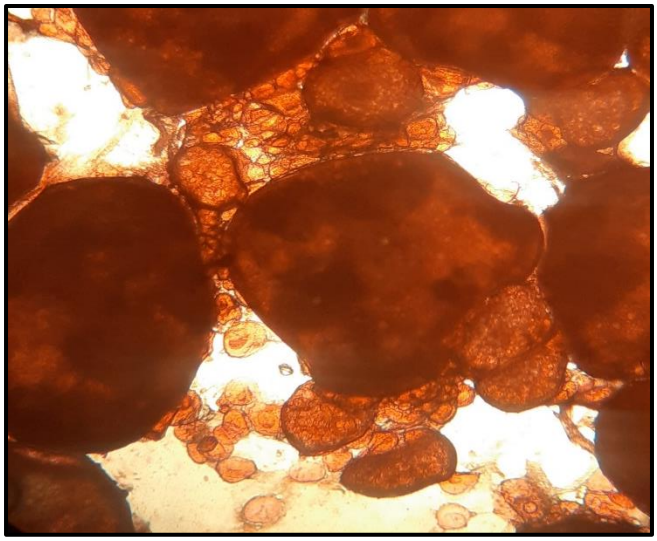


Fig 16*: Amblypharyngodon mola*



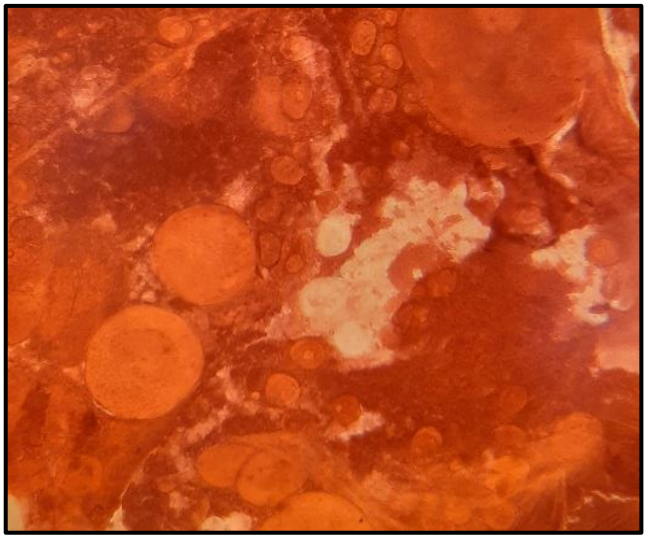


Fig 19*: Heteropneustes fossilis*

Fig 18*: Clarias batrachus*

Fig: Ovarian structure of mature stage of Different species

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Study on Reproductive Biology of some Indigenous Cat Fish

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Abstract

The present study investigates the reproductive biology of selected indigenous catfish species *Mystus tengara*, *Mystus vittatus*, *Clarias batrachus*, and *Heteropneustes fossilis* collected from local markets in Bhopal, Madhya Pradesh, over a five-month period from August to December 2023. The research was conducted at the Department of Zoology and Applied Aquaculture, Barkatullah University, Bhopal. Monthly samples were analyzed to assess variations in total length, body weight, ovary length, ovary weight, Gonado-somatic Index (GSI), fecundity, and ova diameter to better understand the reproductive cycles and spawning seasons of these species. The maturity stages of the gonads were determined through macroscopic examination, and the GSI was calculated using the standard formula to track gonadal development. Fecundity was estimated gravimetrically by counting ova from different regions of the ovary, while ova diameter was measured using an ocular micrometer. The findings revealed distinct seasonal patterns in reproductive parameters among the studied species. Mystus tengara showed peak reproductive indicators in August, with maximum length (15 cm), weight (40 g), and ovary development. In Mystus vittatus, peak reproductive activity occurred in September, whereas in Clarias batrachus, reproductive maturity was most pronounced in October. Heteropneustes fossilis exhibited its highest GSI, ovary length, and weight in September, declining sharply by December. These variations in reproductive traits across species and months highlight their specific breeding seasons and reproductive strategies. The results of this study are significant for formulating conservation strategies and improving captive breeding programs for indigenous catfish in central India.

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Keywords: Reproductive Biology, GSI, Fecundity, Catfish.

1 Introduction

India's freshwater fish diversity includes nearly 2,500 species, primarily grouped into three major families: Cyprinidae, Siluridae, and Channidae, which thrive in various inland aquatic systems. However, a large portion of these species remains insufficiently studied (Malla and Banik, 2015). Among them, catfish classified under the order Siluriformes—represent a remarkably diverse assemblage, encompassing over 3,000 species, 478 genera, and 36 families. They account for around one-third of all freshwater fish species worldwide. In India alone, roughly 158 species of freshwater catfish exist, spread across 50 genera and 13 families. These species are found in diverse habitats, such as high-altitude streams, expansive river systems, and temporary floodplain wetlands, and they display a range of feeding behaviors, including consuming detritus and bottom-dwelling insects. Catfish are easily recognized by their unique barbels—whisker-like structures around the mouth, and unlike most bony fishes (teleosts), they typically lack scales. However, some species, like plecos, are covered in protective bony plates (Jin and Liu, 2016).

Catfish have a global presence, occupying both freshwater and coastal environments across all continents. Fossil records even show their presence in Antarctica, though they are most plentiful in the tropical zones of South America, Africa, and Asia. Comparatively fewer catfish families are found in North America and Europe. Their widespread distribution and rich diversity make them significant subjects for ecological, evolutionary, and biogeographic studies (Sullivan et al., 2006). Highly adaptable and resilient, catfish are ideal for aquaculture. They offer multiple traits favorable for fish farming, including high reproductive output, ease of artificial propagation, adaptability to natural pond conditions, tolerance of low-oxygen environments, resistance to various diseases, and effective feed conversion rates.These features contribute to their popularity and widespread use in aquaculture systems (Liu, 2008).

2 Reproductive Biology

Understanding reproduction is vital in fish biology for the sustainable use and management of fish stocks. Reproductive data provide essential insights into population fluctuations and help formulate effective fishery management strategies [Shalloof and Salama, 2008]. Since reproductive capacity significantly affects population productivity, it also determines how resilient fish populations are to fishing pressure and other human impacts [Ricker, 1954]. Measuring reproductive potential (RP) and recruitment is crucial, although it poses various challenges [Hilborn and Walters, 1992].

Studies focused on breeding seasons and influencing factors are useful for protecting juvenile fish and predicting recruitment trends [Gomez-Marquez et al., 2003]. Reproductive biology encompasses key processes such as sexual maturity, gonad development, spawning period, mating behavior, egg release, and fecundity. Various environmental and genetic factors such as photoperiod, water temperature, turbidity, depth, and food availability, can influence these reproductive processes. Moreover, the quality and viability of eggs and larvae are often related to the size and condition of the female fish, with larger

or more experienced spawners typically producing healthier offspring. In species that spawn multiple times, egg size may also vary across the spawning period (Chambers and Waiwood, 1996; DeMartini, 1991; Kjesbu et al., 1996; Marteinsdottir and Steinarsson, 1998; Rideout et al., 2005b). Reproductive traits such as spawning strategy (batch vs. total spawner, determinate vs. indeterminate spawner) are species-specific, but many reproductive attributes can be flexible and vary across populations or even over time within a population. These variations are often energy trade-offs between growth and reproduction (Rijnsdorp, 1990; Stearns, 1992).

A thorough understanding of reproductive biology is crucial for the conservation of threatened species and the effective management of fisheries (Debnath et al., 2020). Key parameters like the gonadosomatic index (GSI) and fecundity play a significant role in initiating artificial breeding programs and overseeing wild fish populations (Gupta and Srivastava, 2001). The GSI is a reliable measure of reproductive status and aids in determining the timing of spawning periods (Shashi and Singh, 1998). Observing seasonal variations in gonadal development, often through the examination of morphological changes in the gonads, is a useful approach to understanding reproductive cycles (Sivakumaran et al., 2003). Identifying the breeding season is essential for implementing timely conservation actions, such as enforcing fishing restrictions.

3 Fecundity

Fecundity refers to the total number of mature eggs a female fish produces during the spawning season (Alam and Das, 1996). It plays a crucial role in population dynamics, sustainable fisheries, and aquaculture (Bagenal, 1978). Even within the same species, fecundity can vary widely among individuals, often due to differences in feeding success, age groups, or batch spawning behavior (Bagenal, 1957; Saliu et al., 2007). It is also influenced by body length, age, and gonad weight [Lagler, 1956]. Two fish of equal body weight may still have different egg counts, a variability possibly linked to genetic diversity, showing that different strains may mature and reproduce at varying sizes depending on their habitat and ecological factors. Environmental cues such as temperature, daylight duration, and rainfall significantly impact ovarian development and overall fecundity [Lone and Hussain, 2009].

Research indicates that reproductive cycles in fish are closely tied to environmental changes, especially in terms of food availability, photoperiod, and water temperature. Understanding reproductive patterns is essential for managing fish stocks and enhancing species-specific fishery strategies (Iram et al., 2018; Bhat et al., 2010). Since the survival and conservation of fish species depend largely on their reproductive capacity, key indicators such as fecundity and GSI become crucial for evaluating their life history and population health (Shafat et al., 2016). The aim of this study is to determine the reproductive biology of *catfishes H. fossilis*, *Mystus tengara*, *Mystus vittatus*, and *Clarias batrachus*.

4 Methodology

Collection site of species

Fish samples were collected monthly over a five-month period beginning in August 2023 to study their reproductive biology. Specimens were gathered from various markets, including Kasturba, Vijay, Bittan, Govindpura, and Piplani. After collection, the samples were transported to the laboratory and stored in a deep freezer until further examination and analysis. The purpose of sampling was to monitor the monthly changes in gonadal development. For each fish, body weight was recorded using a digital weighing scale, while gonad weight was also measured. Additionally, both standard and total body lengths were measured using a ruler.

Govindpura Market

Vijay Market

Kasturba market

Piplani market

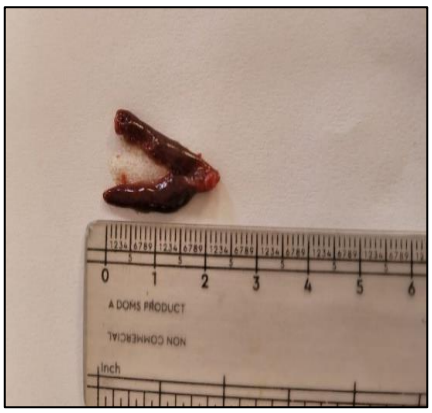
Department Lab: The study was carried out at the Department of Zoology and Applied Aquaculture, Bhopal (Madhya Pradesh).

Department of Zoology and Applied Aquaculture

Length-Weight Measurement

Length of Fish

Dissection of Fish **Removal of gonad**



Length of Gonad **Removal of gonad**

Maturity stage and spawning season

The maturity stages were ascertained on the basis of the degree of development of ovaries. Cycle of gonadal maturation and breeding season has been studied by macroscopic and monthly examination of the different maturation stages of gonad. Gonads have then been grouped into different gonadal stages of development**.**

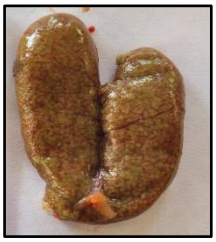
Mystus tengara

Immature	**Maturing**	**mature**	**Spent**
			

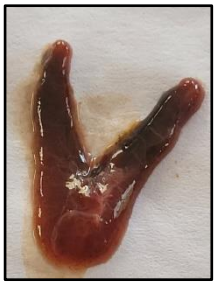
Mystus vittatus

Immature	**Maturing**	**mature**	**Spent**
			

Clarias batrachas

Immature	**Maturing**	**mature**	**Spent**
			

Heteropneustus fossilis

Immature	Maturing	mature	Spent
			

Gonado-Somatic Index (GSI %)

As fish grow, their gonads gradually enlarge and develop toward maturity. Up until the gonads reach the fully ripened stage, their growth tends to be directly proportional to the overall growth of the fish. However, once spawning occurs and the eggs are released, the gonads become spent, leading to a reduction in their weight. Consequently, the Gonado-somatic Index (GSI) increases steadily as the gonads mature, but shows a significant decline following spawning. This index was calculated, and the average monthly values were plotted for analysis. The GSI was determined using a specific formula.

GSI = (Weight of gonad / Weight of fish) × 100.

Fecundity

Gravimetrically, the fecundity of the fish was observed. During the study, the external connective tissues were removed carefully from the surface of the ovaries. With the help of blotting paper moisture of the ovaries was removed. The weight of the ovaries was recorded. Then, the ovary was carefully dissected, and samples were taken from the anterior, middle, and posterior sections of each ovarian lobe. In each portion, the mature and immature eggs were separated and counted. The fecundity of the examined fish was then assessed using the following formula:

Fecundity = (Number of eggs in the sample × Total weight of the gonad) / Weight of the sample.

Additionally, the diameter of the ova was measured at various stages of maturity using an ocular micrometer. (**Figure-1)**

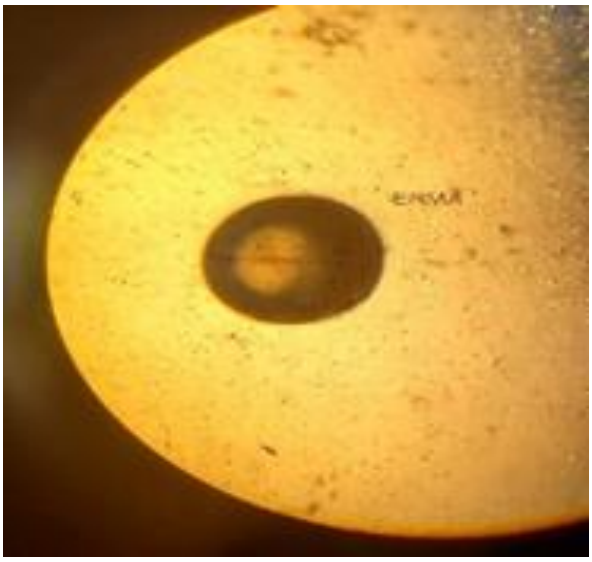


Figure-1 Picture of Ova

Results

Monthly variations of fish length, weight, ovary length, ovary weight and GSI for Mystus tengara, the maximum average length of was on August (15cm). The minimum average length was on December (10cm). The maximum average weight was on August (40cm) and the minimum average weight was on November (10cm).

For Mystus tengara, the maximum average Ovary length of was on August. The minimum average Ovary length was on December. The maximum average Ovary weight was on August and the minimum Ovary average weight was on November. (Table 1 & Figure-2)

Table1: Average Fish length, Fish weight, Ovary length, Ovary weight and GSI of *Mystus tengara*

Months	Fish length	fish weight	Ovary length	Ovary weight	GSI
August	16.69	39.34	4.73	5.87	12.77918
september	13.05	27.37	2.3	2.83	24.26

october	10.07	9.63	-	-	2.13
november	9.81	8.79	-	-	2.85
december	9.5	9.8	-	-	-

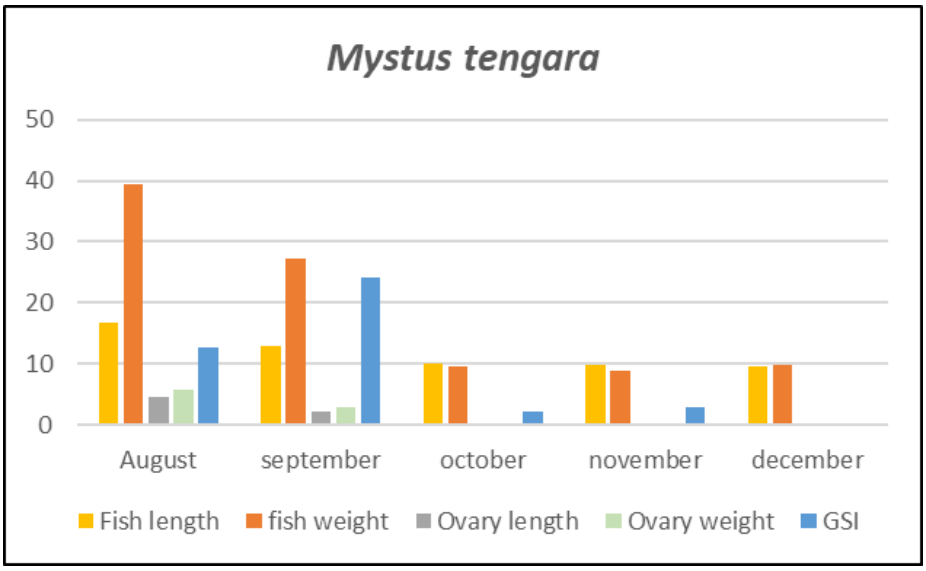


Fig 2: Monthly variation of Fish length, Fish weight, Ovary length, Ovary weight and GSI of *Mystus tengara*

For *Mystus tengara*, the maximum average GSI was on September. The minimum average GSI was on December

Mystus vitattus

For *Mystus vittatus*, the maximum average length of was on September. The minimum average length was on December. The maximum average weight was on September and the minimum average weight was on November. For Mystus vittatus, the maximum average Ovary length of was on September. The minimum average Ovary length was on December. The maximum average Ovary weight was on September and the minimum average Ovary weight was on November. For Mystus vittatus, the maximum average GSI was on November. The minimum average GSI was on December. (Table 2 & Figure-3)

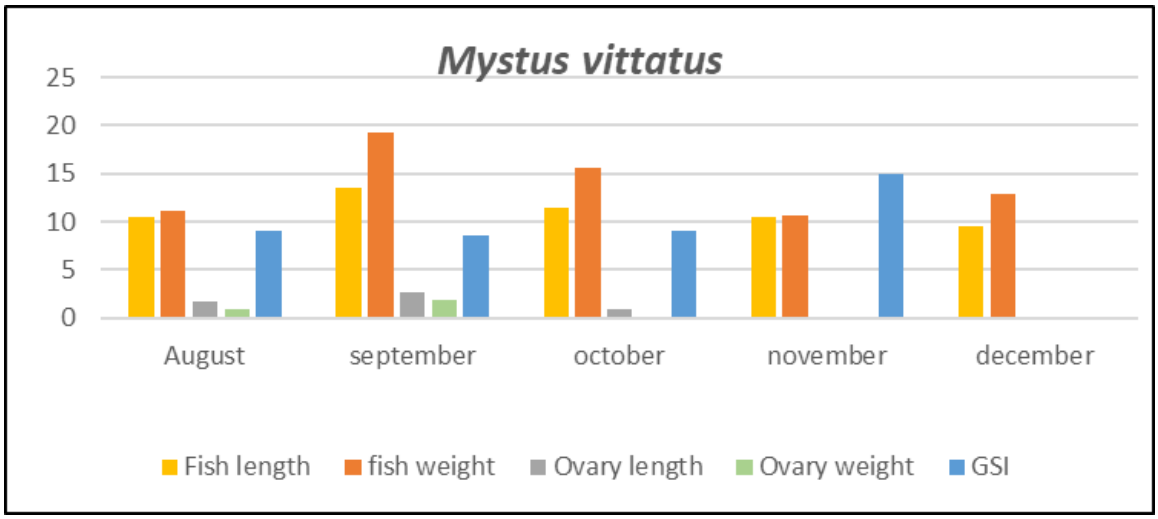


Fig 3: Monthly variation of Fish length, Fish weight, Ovary length, Ovary weight and GSI of *Mystus tengara*

Table 2: Average Fish length, Fish weight, Ovary length, Ovary weight, and GSI of

Months	Fish length	fish weight	Ovary length	Ovary weight	GSI
August	10.55	11.16	1.7	0.87	9.11
september	13.45	19.25	2.725	1.82	8.568
october	11.4	15.64	0.99	-	9.126
november	10.53	10.71	-	-	14.99
december	9.51	12.87	-	-	-

Mystus vittatus

Table 3: Average Fish length, Fish weight, Ovary length, Ovary weight, and GSI of *Clarias batrachus*

Months	Fish length	fish weight	Ovary length	Ovary weight	Average GSI
August	18.67	75.95	2.1	4.5	12.925

september	23.04	196.82	5.36	8.17	4.108
october	23.97	173.07	6.4	12.6	8.01
november	22.3	161.83	3.1	6.5	3.665
december	23.83	154.65	-	-	-

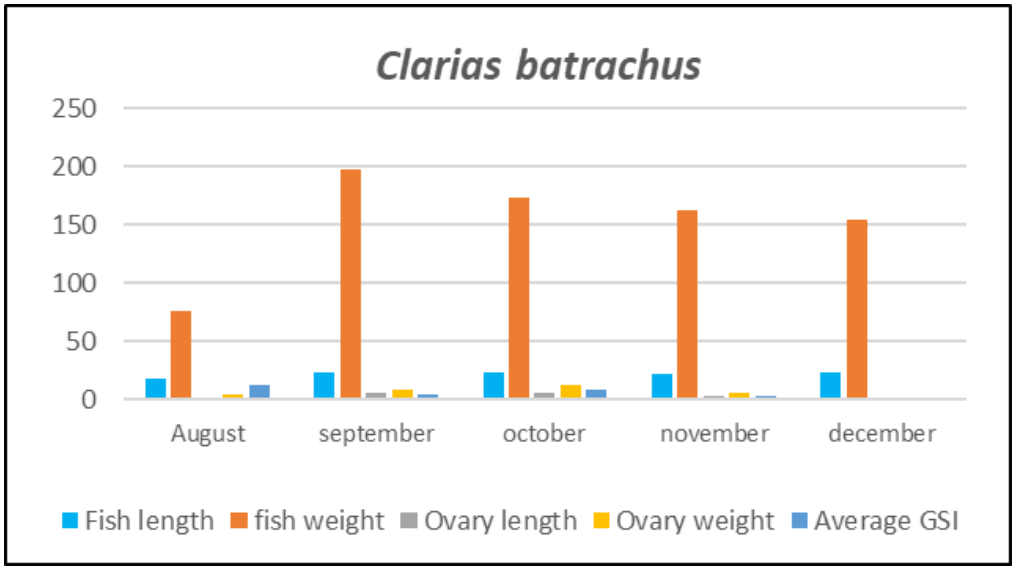


Fig 4: Monthly variation of Fish length, Fish weight, Ovary length, Ovary weight and GSI of *Clarias batrachus*

For Clarias batrachus, the maximum average length of was on October. The minimum average length was on August. The maximum average weight was on September and the minimum average weight was August. In Clarias batrachus, the maximum average Ovary length of was on October. The minimum average Ovary length was on December. The maximum average Ovary weight was on October and the minimum average Ovary weight was on December. For Clarias batrachus, the maximum average GSI was on October. The minimum average GSI was on November.

Table 4: Average Fish length, Fish weight, Ovary length, Ovary weight, and GSI of *Heteropneustes fossilis*

	Fish length	**fish weight**	**Ovary length**	**Ovary weight**	**GSI**

August	20.45	54.99	5.05		12.17	5.14
september	21.7	70.64	5.33		21.9	14.303
october	21.7	70.64	5.3		9.91	9.27
november	16.21	13.93	-		-	11.93
december	17.23	14.35	-	-	-	

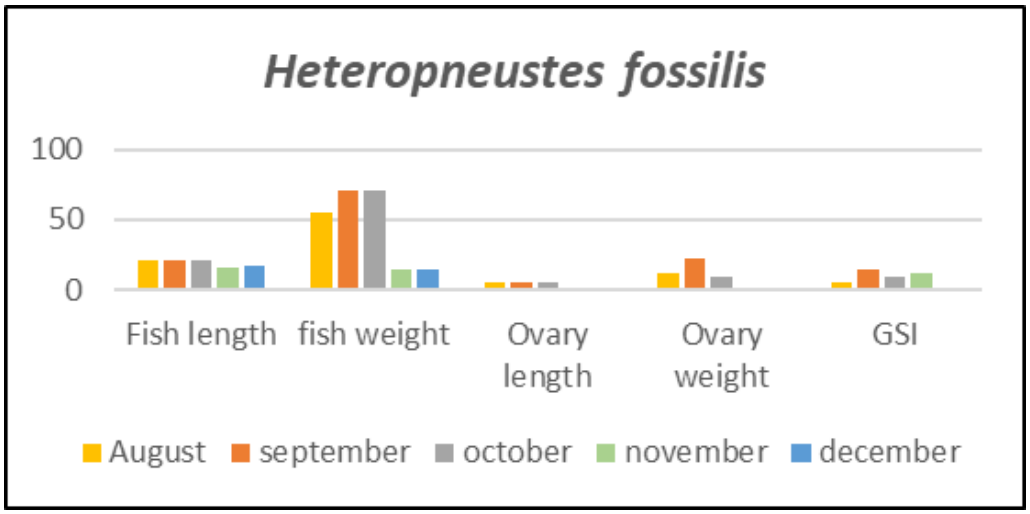


Fig 5: Monthly variation of Fish length, Fish weight, Ovary length, Ovary weight and GSI of *Heteropneustes fossilis*

For, *Heteropneustes fossilis* the maximum average length of was on September. The minimum average length was on November. The maximum average weight was on September and the minimum average weight was November. *Heteropneustes fossilis* The maximum average Ovary length of was on September. The minimum average Ovary length was on December. The maximum average Ovary weight was on September and the minimum average Ovary weight was on December. For Heteropneustes fossilis, the maximum average GSI was on September. The minimum average GSI was on December.

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To study the present status of Wetlands and Rivers and its diversity near Bhopal district, Madhya Pradesh

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Abstract

The present study was conducted to assess the current status of wetlands and riverine fish diversity in and around the Bhopal district of Madhya Pradesh, with specific focus on regions including Bhopal, Sehore, and Berasia. Field surveys were carried out from multiple water bodies such as the Upper and Lower Lakes of Bhopal (Bhoj Wetlands), the Parbati River in Sehore, and various ponds and reservoirs in Berasia including Goretia Talab, Sagoni Kalan, and Semri Kalan. Data were collected through field observations, interaction with local fishers and vendors, and secondary data sources including scientific literature and IUCN assessments. A total of 54 fish species belonging to 12 orders and 23 families were recorded, with Cyprinidae being the most dominant family comprising 20 species, followed by Bagridae and Channidae. The study noted a concerning decline in the population of Small Indigenous Fish species (SIF), attributed to the presence of invasive and predatory species like *Hypophthalmichthys molitrix* and *Clarias gariepinus*, along with anthropogenic pressures such as pollution, habitat degradation, siltation, and unregulated aquaculture. According to the IUCN Red List, the majority of species observed were categorized as Least Concern, while others such as Tor tor were listed as Endangered, *Wallago attu* as Vulnerable, and species like *Ompok bimaculatus* and *Chitala chitala* as Near Threatened or Data Deficient. This study highlights the rich yet threatened fish biodiversity of the Bhopal region and underscores the urgent need for conservation efforts. Recommended strategies include controlling

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invasive species, promoting sustainable aquaculture, preventing overharvesting, and restoring natural wetland habitats. These actions are vital for preserving the ecological integrity of central India's freshwater ecosystems and safeguarding indigenous aquatic biodiversity for future generations.

Keywords: Present Status, Diversity, Wetlands , Rivers

1 Introduction

These aquatic habitats contribute significantly to the socio-economic and ecological well-being of the region, serving as sources of livelihood for local communities and playing crucial roles in nutrient cycling and water purification. However, the current status of fish species in these water bodies is subject to various environmental challenges and anthropogenic pressures.

Understanding the diversity and present status of fish species is essential for effective conservation and management strategies. Factors such as habitat degradation, pollution, overfishing, and the introduction of non-native species pose threats to the delicate balance of these aquatic ecosystems. Conservation efforts are crucial to ensure the sustainability of fish populations and the overall health of these water bodies.

This exploration aims to delve into the richness of fish species inhabiting the rivers, lakes, and wetlands in Bhopal and its rural surroundings. By examining the current state of these aquatic ecosystems, we can better appreciate the importance of their conservation and work towards preserving the delicate harmony between humans and the diverse aquatic life that thrives in these waters.

Wetlands are highly productive, dynamic systems experience frequent changes in abiotic and biotic factors. Being dynamic ecosystems, they offer heterogenous habitats during the year supporting diverse life forms. They are major source of food hence attract many animals. Fish community of wetland resources play a major role in wetland ecosystems by recycling the organic matter and converting it into valuable protein which is used as food by humans apart from other animals also.

2 Materials and Method

Description of Study Area

The present study was conducted in selected sites District Bhopal, Sehore, and Berasia,. As the capital of Madhya Pradesh, Bhopal is often referred to as the "City of Lakes" due to its numerous natural and artificial lakes.

Geographic Coordinates: 23°15′35.6″N, 77°24′45.4″E

Study Areas: Bhoj Wetlands, which include the Upper Lake and Lower Lake.

Sehore: Located in the Sehore district of Madhya Pradesh, this city and municipality lies within central India.

Geographic Coordinates: 23.2°N, 77.08°E

Study Areas: Parbati River and Behrawal Village.

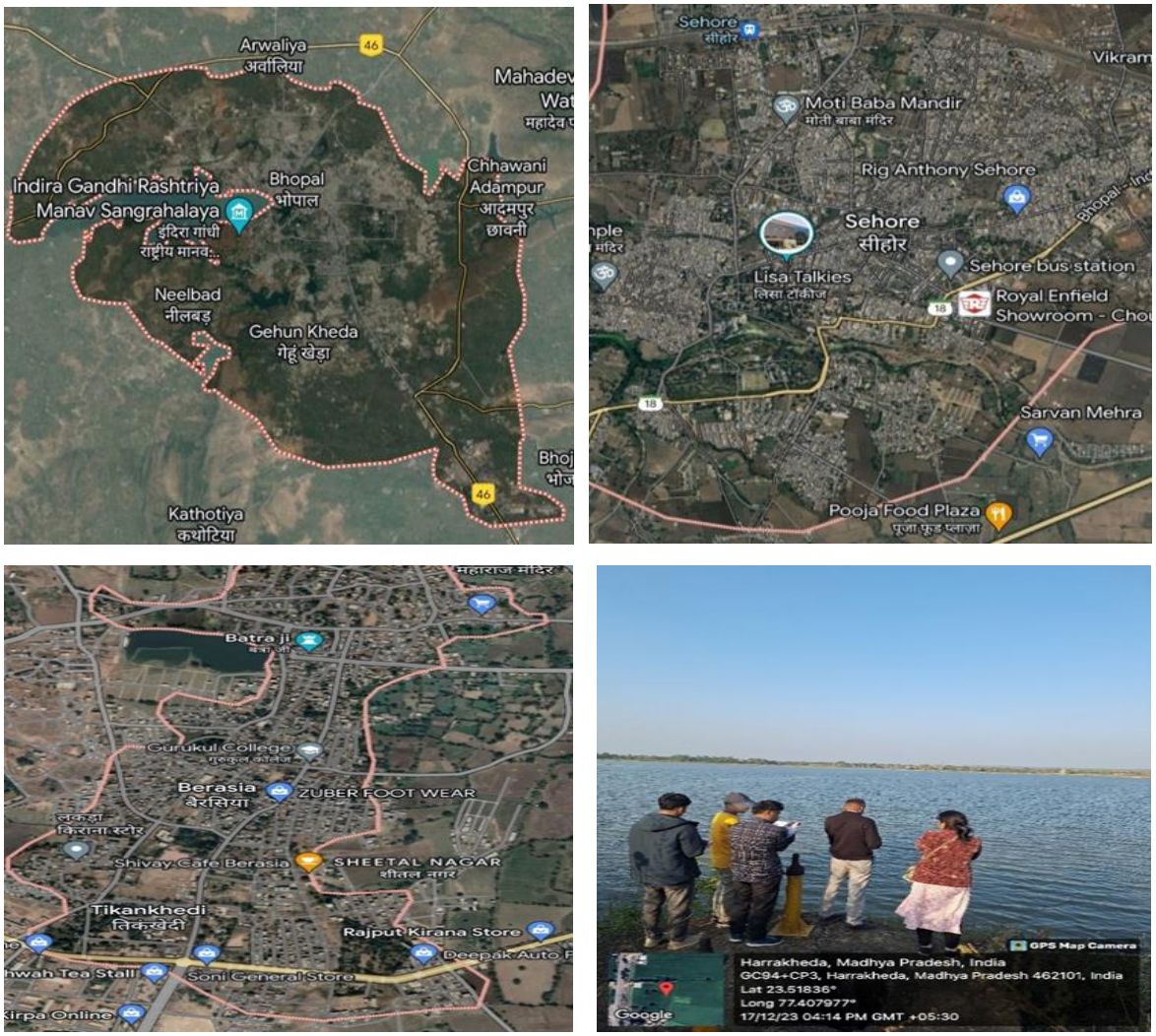
Berasia: A town and municipal council (nagar palika) in Bhopal district, Madhya Pradesh.

Geographic Coordinates: 23.63°N, 77.43°E

Study Areas: Sagoni Kalan, Semri Kalan, Karondiya, Kadhampur, Kothar, and Goretia Talab.

The sites of the study are illustrated in Figure 1. Photographic scenarios of wetlands are highlighted in (Figure 2)

Data collection: Primary data was collected through the use of semi structured questionnaire, picture book administered through the farmers, fishermen's, fish mongers, and Secondary data obtained from research papers. Tables 1 and 2 highlight information regarding the status of Present diversity, threatened, endangered, and extinct species.

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Result and Discussion

Table 1: Berasia

Showing the list of fish indentified during present study area at Berasia block [District Bhopal]

S.No	Species	Garethiya Talab	Manikhedi talab	Kalyanpur talab	Sagoni talab	Semrikalan talab
1	*Notopterus notopterus*	+	+	+	+	+
2	*Gudusia chapra*	+	+	+	+	+
3	*Catla catla*	+	+	+	-	+
4	*Cirrhinus mrigala*	+	+	-	-	-
5	*Cirrhinus reba*	-	-	-	-	-
6	*Cyprinus carpio*	-	-	-	-	-
7	*Labeo rohita*	+	+	+	+	+
8	*Labeo calbasu*	+	+	+	+	+
9	*Labeo gonius*	+	+	+	+	+
11	*Labeo bata*	-	-	-	-	-
12	*Osteobrama cotio*	+	+	+	+	+
13	*Puntius sophore*	+	+	+	+	+
14	*Puntius sarana*	+	+	+	-	-
15	*Puntius chola*	+	+	+	+	+
16	*Puntius ticto*	+	+	+	+	+

17	*Ctenopharyngodon idella*	+	+	+	-	-
18	*Hypopthalmichthys molitrix*	-	-	-	-	-
19	*Amblypharyngodon mola*	+	+	+	+	+
20	*Rasbora daniconius*	+	+	+	+	+
21	*Salmostaoma bacaila*	+	+	+	+	+
22	*Esomus danricus*	+	+	+	+	+
23	*Barilus barila*	+	+	+	+	-
24	*Lepidocephalus guntia*	+	+	+	+	+
25	*Nemachelus botia*	+	+	+	+	+
26	*Mystus bleekeri*	+	+	+	+	+
27	*Mystus cavasius*	+	+	-	+	+
28	*Aorichthys aor*	+	+	+	+	-
29	*Sperata seenghala*	+	+	+	+	+
30	*Ompok bimaculatus*	+	+	-	-	-
31	*Wallao attu*	+	+	+	+	+
32	*Clarias batrachus*	+	+	+	+	+

33	*Heteropnuestus fossilis*	+	+	+	+	+
34	*Xenentodon cancila*	+	+	+	+	+
35	*Mastacembelus armatus*	+	+	+	+	+
36	*Mastacembelus pancalus*	+	+	+	-	-
37	*Nandus nandus*	+	+	+	+	+
38	*Chanda nama*	+	+	+	+	+
39	*Parambassis ranga*	+	+	+	+	+
40	*Glossogobius giuris*	+	+	+	+	+
41	*Anabas testudineus*	+	+	+	+	+
42	*Tricoglaster fasciata*	+	+	+	+	+
43	*Channa marulius*	+	+	+	+	+
44	*Channa striatus*	+	+	+	+	+
45	*Channa punctatus*	+	+	+	+	+
46	*Oreochromis mossabica*	-	-	+	-	-

Showing the status of fishes in terms of family:

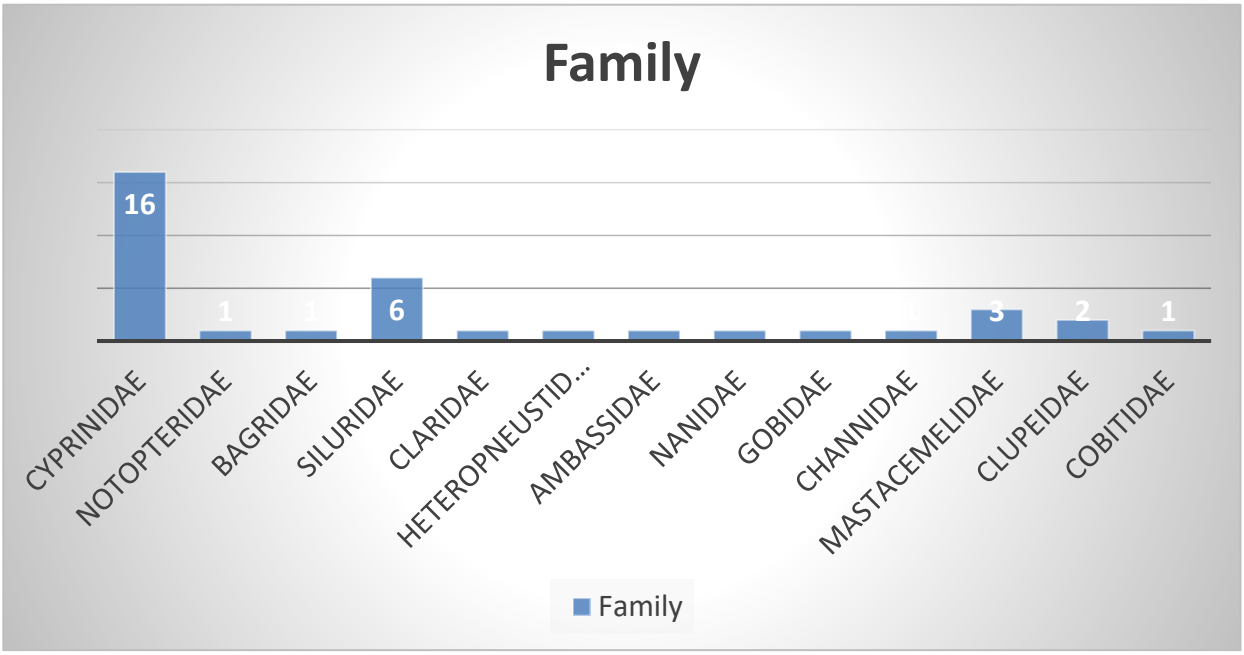


Table 2: Bhopal

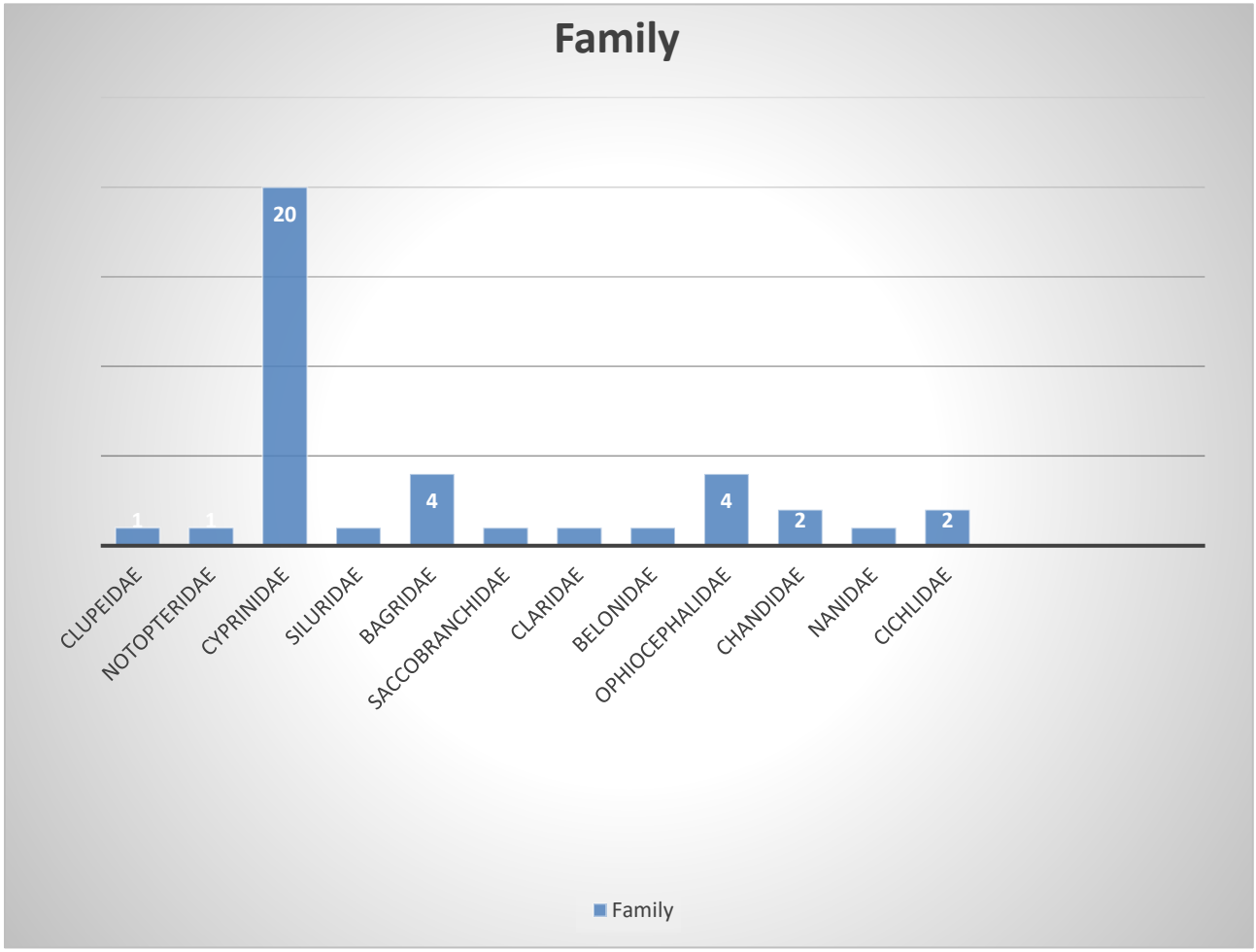
Showing the list of fish identified during present study area at Upper lake and lower lake

S.no	Order	Family	Species
1	Clupeiformes	Clupeidae	*Gudusia chapra*
		Notopteridae	*Notopterus notopterus*
2	Cypriniformes	Cyprinidae	*Labeo catla*
			Barilius bendelisis
			Labeo calbasu
			Labeo rohita
			Labeo gonius *Labeo bata*

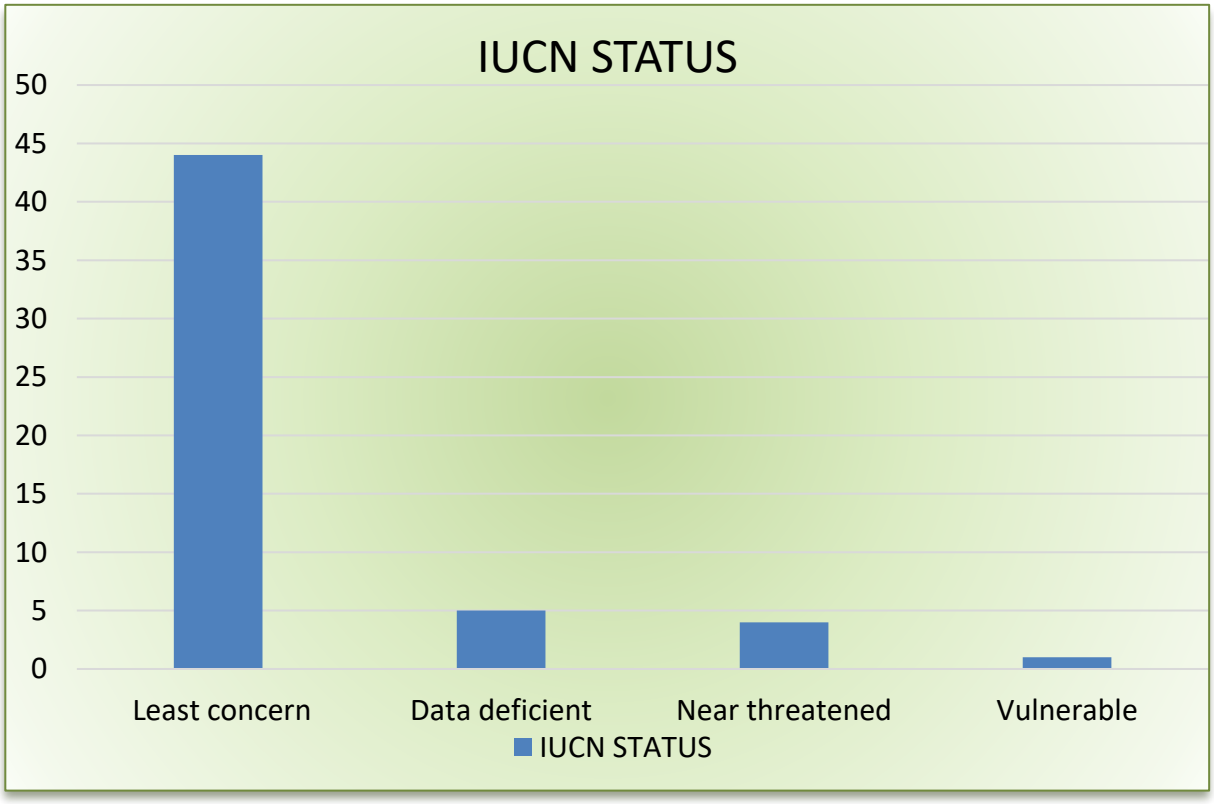
			Labeo dussumeri
			Osteobrama cotio
			Oxygaster bacalia
			Cirrhinus reba *Cirrhinus mrigala*
			Garra gotyla
			Esomus danricus
			Puntius sophore
			Puntius ticto
			Puntius sarana
			Rasbora danoconius
			Cyprinus carpio
		Siluridae	*Ompok bimaculatus*
		Bagridae	*Mystus cavasius*
			Mystus seenghala
			Mystus bleekeri
			Mytus aor
		Saccobranchidae	*Heteropneustus fossilis*
		Clariidae	*Clarias batrachus*
3	Beloniformes	Belonidae	*Xenentodon cancila*
4	Ophiocephaliformes	Ophiocephalidae	*Channa straitus*
			Channa punctatus

			Channa marulius
			Channa gachua
5	Perciformes	Chandidae	*Parambassis ranga*
			Chanda nama
		Nandidae	*Nandus nandus*
6	Cichliformes	Cichlidae	*Oreochromis niloticus*

Showing the status of fishes in terms of Family



IUCN status



According to IUCN redlist.org which gets updated every 2 years 44 species were listed as least concern.Hypopthalmichthys molitrix, Ompok pabda, Ompok bimaculatus, Chitala chitala, were listed as near threatened, Wallago attu listed as vulnerable, and Tor tor was listed as endangered, whereas species such as Mastacembelus armatus, Mastacembelus pancalus were listed as data deficient.

Discussion

A total of 54 fish species was collected from the studied area of which 20 species belonging to the cyprinidae family, followed by bagridae with 6 species, channidae with 3 species, siluridae, ambassidae and nanidae with 2 species each, cichlidae with 2 species followed bynotopteridae, clupeidae, belonidae, gobiidae etc.

The areas from where the specimens were collected are most seasonal.SIF were mostly absent in these ponds, these could be due to the presence of invasive species such as Hypopthalmichthys nobilis and Clarias gariepinus which are voracious feeders.According to the IUCN Redlist.org, 44 species were listed as Least concern, Tor putitora was listed as endangered, *Hypopthalmichthys molitrix*, *Ompok bimaculatus*, *Ompok pabda*, *Chitala chitala* are listed as near threatened, Wallago attu listed as

vulnerable, whereas species such as Tor tor, *Mastacembelus armatus, Mastacembelus pancalus* listed as data deficient.

3 Conclusion

The study indicates a decline in the fish species, especially small indigenous fishes.Factors contributing to this reduction include habitat loss, degradation, water abstraction, drainage of wetlands, dam construction, pollution, and eutrophication. The fish community in water bodies consists of both native and exotic species, with the latter introduced for fish production purposes. Certain species are experiencing a decline in population due to various anthropogenic activities affecting their habitats. The total diversity of fish species in the Bhopal district is still regarded as rich, even though some species have declined. The study highlights the necessity for conservation efforts by pointing out that invasive species are replacing numerous indigenous and native species.

The following are important fish conservation strategies:

1. Halting siltation to protect aquatic habitats.

2. To prevent overexploitation, encourage restricted harvesting.

3. Investigating strategies to limit the spread of invasive species.

4. Carefully consider the cultivation of prohibited species such as *Clarias gariepinus* and *Hypophthalmichthys nobilis*.

In the area under study, exotic species like tilapia are frequently seen. Due to their competition for food, habitat, and shelter, these species which are known to be voracious feeders endanger endemic species. In the area under study, wetlands are mostly utilized for irrigation. Production is poor in aquaculture-practicing areas, maybe as a result of the widespread adoption of intensive farming techniques. The study concludes that in order to preserve the variety of fish species found in the Bhopal district, urgent conservation actions are required. To preserve ecological balance and the region's rich aquatic biodiversity, these policies should include habitat preservation, restricted harvesting, and cautious invasive species management.

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