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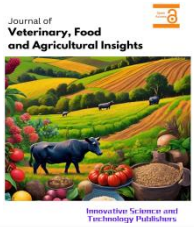

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Review Article

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A review and analysis of the effect of water temperature on the reproductive performance of indigenous and exotic species of fish in Pakistan: Through induced breeding in a controlled environment

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ABSTRACT

Indigenous species of fish like major carps *(Gibelion catla, Labeo rohita, Cirrhinus mrigala) Catla catla, Labeo bata, Labeo victorianus, Puntius pulchellus*, and exotic species like Chinese carps (*Hypophthalmichthys nobilis, Ctenopharyngodon idella, Hypophthalmichthys molitrix*) *Mylopharyngodon piceus, Rita rita, Clarias macrocephalu, Cyprinus carpio, Carassius auratus, Dawkinsia filamentosa, Clarias gariepinus, Channa striata, Lophiosilurus alexandri, Heteropneustes fossilis, Cyprinus rubrofuscus, and Garra rufa* are commercially important, *were* introduced in Pakistan's freshwater for aquaculture to fulfil the growing demand for fish meat. These are economically significant because of their fast growth rate, high fecundity, fertility rates, and hatching rates. They breed in the river naturally. They need stimulation for spawning. In induced breeding, the exogenous hormones are injected into the bodies of mature brooders. The internal condition of the fish body and environmental factors like water temperature can trigger the reproductive performance of fish species. Reproductive performance of fish is directly affected by water temperature. When the water temperature rises to the upper threshold temperature, the latency time and hatching activity in freshwater fish species accelerate. The spawning response time, fertilization rate and hatching activity are non-linear or practically zero when the water temperature rises beyond the upper threshold temperature or falls below the lower threshold temperature. This study could help to comprehend how degree-hours impact fish spawning behaviour, oocyte rates, and hatch rates.

Keywords: Indigenous species; Exotic species degree hours; Fertilization rate; Hatching rate; Ovulation rate

INTRODUCTION

Pakistan is the nation with the greatest diversity of native and foreign species of freshwater fish (Haseeb and Yousafzai 2023). It officially confirms 531 fish species, including 233 freshwater fish, with 193 native species found in freshwater bodies (Iqbal et al. 2023; Rafique and Khana 2012). 31 edible freshwater fish species are raised through pond-based aquaculture. A three-years study has been carried out in Pakistan's Punjab freshwater bodies since 2017-2019 (Inayat et al. 2023; Bibi et al. 2018). In the current survey, fish species from the Head Baloki, head Qadirabad, Islam headworks, and Rasul barrage totaled 68 (local and exotic), representing 14 families. The Rasul Barrage and Islam Headworks had the highest Shannon-Wiener diversity index (1.41), but very few invasive species such as Chinese carps, i.e., grass carp and silver carp (Atique et al. 2022; Imran et al. 2021). Different types of non-native fish have been introduced into Pakistan's aquatic bodies, causing competition with the local fish fauna and creating many problems for freshwater fish, depriving them of shelter, habitat, and food in addition to their sizeable local counterparts (Hussain et al. 2015). A key issue for the

biodiversity of an invaded area is the deliberate or unintentional introduction of organisms outside of their natural niche (Rafique and Khan 2012). The diversity of native fishes is impacted by a variety of circumstances, but alien (invasion) fish may have a significant negative impact on local fish fauna because they compete with them for resources. Therefore, it will soon be urgently necessary to analyze Pakistan's native and foreign food webs and roosting locations (Imran et al. 2021).

Indigenous Species of Pakistan

Indigenous species, like major carps *(Labeo rohita, Cirrhinus mrigala,* and *Gibelion catla) and minor carp* are the inhabitants of Ganga River channels in North India, Pakistan, Nepal, and Burma (Azhar et al. 2023; Sheikh et al. 2017; Alam et al. 2009). Spawning season often corresponds with the monsoon (Dasgupta et al. 2009). In rivers that are under water, spawning takes place. These fish obtained maturity in stagnant water and did not breed here. They need stimulation for spawning (Bais, 2018). Temperatures below 22°C and above 32 °C have the potential to rapidly reduce spawning activity in major carps (Azhar et al. 2022). These fish have egg production potentials of about 1.5-2.00 lac/kg body weight. Freshwater fish breeding habitats might produce fry and fingerlings to overcome the demand for food (Tripathi et al. 2017). Even though fish eating is highly recommended for children's nutrition, the safety and quality of the product should constantly be examined to preserve public health (Saha et al. 2016). They must be encouraging in ways that prop up measurable nutrition, which consists of minerals and vitamins, and health gains (Thilstedet et al. 2016). The cornerstone of freshwater aquaculture is Indian major carp (Soni and Ujjania 2017). Due to their significantly faster growth than that of other species, these fish are the most popular and acceptable (Paul et al. 2016). Most of the experimental studies have revealed that major carp grow best at dietary protein levels of 28-35%, with metabolizable energy (Azhar et al. 2022; Mishra, 2021).

Exotic Species of Pakistan

Pakistan is introducing exotic freshwater fish species for aquaculture, including *Hypophthalmichthys nobilis*, *Ctenopharyngodon idella*, *Cyprinus carpio*, *Hypophthalmichthys molitrix*, *Dawkinsia filamentosa, Rita rita, Carassius auratus, Mylopharyngodon piceus, and Garra rufa* and three tilapia species in warm water environments (Imran et al. 2021: Latif et al. 2018). China-originating carp species possess unique genetic traits, enabling them to withstand harsh environmental conditions like low oxygen, high temperatures, and parasitic infections, making them adaptable to both alkaline and acidic environments. April marks the start of the spawning phase, which ends in July in Pakistan. Since they are ectothermic fish, Chinese carps are particularly sensitive to changes in temperature (Brulé et al. 2022: Ashaf-Ud-Doulah et al. 2021). Temperatures below 18 °C and above 30 °C have the potential to rapidly reduce spawning activity in Chinese carps (Szabó et al. 2019).

Induced Breeding

Induced spawning is a management technique used to increase egg production in large carps by injecting synthetic hormones like Ovaprim into the intramuscular body (Azhar et al. 2022). These hormones affect reproductive function, specifically gonads (Zadmajid et al. 2017). Artificial agonists of gonadotropin-releasing hormone (GnRHa) release endogenous LH reserves, stimulating spermiation and steroidogenesis. Dosages for hormones vary between species. In recent decades, pituitary extracts have been used to induce breeding, but the cost of donor pituitary has increased (Berlinsky et al. 2020). This type of injection was given at an angle of 40º to 50º between the dorsal line and the lateral line of scale (Azhar et al. 2022). The internal condition of the fish body and environmental factors like water temperature can trigger the reproductive performance of native and exotic fish species (Betsy and Kumar 2020).

Effect of Temperature on the Reproductive Performance of Indigenous Species

In an experimental study, the degree-hours required for successful spawning and hatching were compared, and the ovulation, fertilisation, and hatching rates of two major carp species *Labeo rohita* and *Cirrhinus mrigala* were determined through induced breeding using synthetic ovaprim hormones. According to these results, degree hours have a direct impact on the spawning response and hatching of *C. mrigala* and *L. rohita*. Based on this study, it can be concluded that successful spawning took place in *L. rohita* following the latency period in 9.35±0.4299 hours (561 minutes) at 248.6±9.35 degree-hours, and in *C. mrigala* 10.18±0.4393 hours (610.8 minutes) at 264.6±5.625 degree-hours.

The ovulation rate in both species was 100%. The average fertilisation rate for *C. mrigala* was found to be 87.23±2.029%, but it was found to be 85.75±1.856 % for *L. rohita*. On average, the hatching rates of *L. rohita* and *C. mrigala* were observed to be (81.75±1.525%) and (84.88±1.7747%), respectively. For *L. rohita*, the hatching process took 29.75±0.85 hours at 741.025±14.532 degree-hours, and for *C. mrigala*, it took 31.2±0.648 hours at 778.43±9.1972 degree-hours (Azhar et al. 2022). Similarly, Alam et al. (2022), explored a study to estimate the effect of local and overseas carp pituitary glands on *C. mrigala* through induced breeding at a hatchery in Jashore, Bangladesh. Both male and female brooders were given the initial dosage of PG hormone at 0.5 mg/kg body weight, using domestic and foreign CPG. Only female brooders were administered the second dosage of PG at 5 mg/kg body weight after 6 hours had passed since the first treatment. Both domestic and foreign PGs, which are synthetic compounds, had 100% estimated ovulation rates. For local and foreign PG, the fertilization rates were determined to be 93.5% and 92.6%, respectively, while the hatching rates were computed at 91.2% and 89.5%. Within 42-48 hours of the second injection of the PG hormone, fertilized eggs began to hatch. This process took another 6-7 hours. Regarding the pace of fertilization and hatching, local CPG is strongly advised to hatchery owners.

Ashaf-Ud-Doulah et al. (2021), conducted an experiment to investigate the impact of water temperature on Indian carp embryonic development. The results showed that temperatures above the upper thermal limit disrupt embryonic development. The current study involved the cultivation of Rohu embryos and larvae at temperatures ranging from 30 to 36 °C in order to examine their developmental. The highest rates of successful hatching occurred in Indian major carp embryos that were exposed to 30 and 32°C. Indian major carp embryos at 34°C had the shortest incubation times and the lowest hatching rates, as well as damaged zygotes. Iqbal et al. (2021), observed the impact of temperature variation on *C. mrigala* breeding behaviour during induced spawning at UVAS, Punjab, Pakistan. This study was divided into four trails in different temperature ranges to determine the impact of temperature variation on breeding behaviour during induced spawning at UVAS, Punjab, Pakistan. The synthetic hormone Ovaprim was administered to brooders to induce spawning. Spawning occurred within 9.79 hours, 9.59 hours, 10.70 hours, and 11.32 hours at temperatures of 26, 29, 31, and 34°C, respectively. Maximum fertilization rate and hatching were observed at a temperature of 29°C. This study shows that an increase in temperature decreases the latency period and hatching time up to a certain limit. Similarly, Mohapatra et al. (2018), performed an experiment on major carps such as Rohu, Mrigala, and Catla for seed production in the FRP Hatchery in Odisha, India. They used a synthetic hormone like Ovatide for induced breeding. Ovatide was injected into brooder from monsoons until July at a temperature range of 27-34 ºC. Spawning occurs after a latency period of 342-400 minutes (5.7-6.7 hours). The fertilization rate in major carps was found to be in the range of 91.7-97.5%. The highly effective and successful spawning period was 62%, 53.5%, and 40% *Labeo rohita*, *Catla catla*, and *Cirrhinus mrigala*, respectively.

In India, Mohapatra et al. (2016), investigated the seed production of major carp and minor carp on a remote island in the Indian Sunderban. Induced breeding in carp was done during July-August. The recommended dose of hormone for male brooders such as *L. rohita* and *C. mrigala* is 0.2 mg/kg, but 1.5 mg/kg is injected into males (*L. bata*). The fish was ready for ovulation after 6 hours of injection to complete ovulation. Artificial hormones were injected into brooders to stimulate ovulation and spermitation. Hatching was completed in *Labeo Rohita in 920-970* minutes. Fertilization rate in Rohu was found to be 90-95% at a temperature range of 28.3-32.6 ºC. Chaturvedi et al. (2015) performed breeding experiments on *C. catla* at Choudhri Farms in India. Three artificial hormones Ovaprim, Ovatide, and gonopro-FH were tested to assess how well they caused ovulation in carps. Under the ideal temperature range 28-29 ºC, spawning was observed within 10-13 hours in *C. catla.* The level of fertilization in carps injected with Ovaprim and Ovatide ranged between 60 and 70%. *C. catla* laid 1,80,000, and 1,60,000 good-quality eggs were produced from carps that had been given Ovaprim and Ovatide. However, stripping was done on female silver carp brooders, and ovaprim produced 1,60,000, 1,40,000, and 1,80,000 good eggs. Ovatide was discovered to be a more effective synthetic hormone analogue for inducing silver carp spawning. In Bangladesh scientists investigate the rate of spawning and hatching of two major carps (*L. rohita* and *C. mrigala*), and one minor carp (*L. bata*). Liquid

ovaprim is injected into both male and female brooders, which is a stimulant for the successful spawning and hatching of fish. The recommended dose of hormone for male brooders such as *L. rohita* and *C. mrigala* is 0.2 mg/kg, but 1.5 mg/kg is injected into males *L. bata*. The fish was ready for ovulation after 6 hours of injection to complete ovulation. The latency time period was 9-10 hours recorded. The time required for the completion of hatching was about 18-24 hours. The maximum fertilization rate was observed in *C. mrigala* between 88.53 and 89.94%. The lowest fertilization rate was observed in *L. rohita* between 87.0 and 9.11%. Hatching rate was determined between 77.27-79.54% in *L. rohita*, 78.13-80.19% in *C. mrigala*, and 64.9-66.56% *L. bata* (Mondol et al. 2014).

Sridhar et al. (2014) concluded a research experiment on Indian medium carp (*Puntius pulchellus*) to observe the larval and embryonic development by induced breeding at 26 ºC. Fish was injected with a hormone composed of salmon gonadotropin, which releases the hormones analogue and dopamine. They inject pituitary extract at 8 mg/kg and 2 mg/kg into male and female brooders, respectively. Hatching was completed within 48 hours, and larvae appeared. Similarly, a study was performed to evaluate the spawning efficacy of the ovaprim hormone ovatide on *C. catla, L. rohita, C. mrigala, H. molitrix*, and *C. idella* at the Government Fish Seed Hatchery, Bahawalpur. The synthetic product Ovatide, which is a GnRH analogue and a dopamine antagonist, was injected into brooders to induce spawning. A comparison was carried out to check the fertilisation rate, response time, and hatching rate of carp. Ovatide hormone is more effective in native carp as compared to exotic carp. Spawning occurred within 7.45-8.30 hours in *Labeo Rohita* at a temperature range of 29 ºC. Fertilization rate was found in *Labeo rohita at* 30-80%, while in *C. mrigala* it was 43-77% at 27 ºC (Khan et al. 2013).

Minar et al. (2012) performed an experiment in 21 hatcheries in Barisal district, Bangladesh, to investigate the ovulation period and hatching rate. They selected five indigenous species for induced breeding, namely Rohu, Mrigala, Catla, Bata, and Sarpunti. They also selected five exotic species, such as silver carp, grass carp, common carp, and mirror carp. Their weight was between 0.25 kg and 0.8kg. Different fishes ages ranged from one to ten years. For native species, two hormone types, PG and HCG, are employed. The first dose of PG, 1-4 mg/kg, was administered to native species. Exotic species were injected with a dosage of 150-500 IU/kg. The second doze of PG was injected into native and exotic species with 4-8 mg/kg and 4-10 mg/kg, respectively. Ovulation time and hatching rate vary from 1.5 hours to 6 hours and 47-86%, respectively. In India Tiwana and Raman (2012), evaluated an experiment on *Labeo rohita* at the carp fish hatchery in Fathegarh Sahib, Punjab, India. By inducing breeding at a temperature of 28°C, they conducted this study to examine the effectiveness of three hormones, including ovaprim, ovatide, and carp pituitary extract. These hormones were injected into their bodies in proportion to their body weight in kilograms. With ovaprim, ovatide, and carp pituitary, their eggs were fertilized at rates of 61.30%, 58.50%, and 55.96%, respectively. For hormones like ovaprim and ovatide, spawning happens 9 hours after injection, while for carp pituitary extract, spawning is finished 16 hours after injection. Rokad et al. (2006) examined a research experiment on a major carp *C. mrigala* at Paithan Fish Farm, a Chinese hatchery in India, at a temperature range of 24-28°C. They performed this study to determine the efficiency of hormone and pituitary extract. These hormones are administered to their bodies in different dosages according to their body weight. The result of the ovaprim hormone was satisfied and gave a good spawning response. Ovulation occurs within 9 hours after the injection of the ovaprim hormone. The fertilization rate was 91%. Rutaisire and Booth (2004), evaluated an experiment on *L. victorianus* under control conditions to induce spawning, egg incubation, and hatching at Sio River and Kajansi Aquaculture Research Station Ugtmda on Lake Victoria. Aquaspawn was used for induced breeding in *L. rohita*. Successful ovulation appeared when the oocyte became transparent. Fertilization rate was greater than 69%. Hatching occurred after 26 hours and lasted 8 hours at a temperature of 24 ºC.

In Canada, Nandeesha et al. (1990), selected three species of Indian large carps, the catla (*C. catla*), Rohu (*L. rohita*), and Mrigala (*C. mrigala*), and used them to evaluate the effectiveness of the novel medicine Ovaprim-C, produced by Syndel Laboratories in Canada. The medication combines domperidone, a dopamine antagonist, and a salmon gonadotropin analogue that was created. Using separate dosages of fish pituitary extract, one dosage of fish pituitary extract, or a single dose of Ovaprim solvent, the breeding response of three carps was contrasted to that of the controls. Each of

the three species could procreate following one intramuscular administration of ovaprim at a dosage of 0.5 ml/kg body weight. 0.4 ml/kg was shown to be the absolute minimal dose required for rohu, nevertheless. Even smaller amounts of 0.3 and 0.4 ml/kg induced Mrigala to react well. Males were given an injection of the carp hypothalamus extracts at an amount of 3-4 mg/kg in each of these experiments, 6 hours after females received Ovaprim injections. In another study, spawning response was extremely good when male and female Rohu got Ovaprim doses at dosages of 0.4 and 0.15 ml/kg, respectively. In contrast, the control fish that received a single dosage of pituitary extract did not react. In the majority of instances, the fertilization rate was between 70% and 99%. The findings of this experiment unequivocally show that Ovaprim-C is suitable for stimulating reproduction in Indian major carps (Table 1).

Table 1. Effect of water temperature on the reproductive performance of indigenous species of Pakistan.

Sr.	Species Name	Experimental Site	Aver. Temp (°C)	Ovulation rate (%)	Spawning time (hours)	Fertilization rate (%)	Hatching time (hours	Reference
1	*Labeo rohita*	Islamabad, Pakistan	26.3	100	9.35±0.42	85.75±1.856	29.75±0.8	(Azhar et al., 2022)
2	*Cirrhinus mrigala*		26.3	100	10.18±0.43	87.23±2.029	31.2±0.64	
3	*Labeo rohita*	Bangladesh	32	100	8.14	88.45±6.05	13.30	(Ashaf-Ud-Doulah et al., 2021)
4	*Cirrhinus mrigala*	Punjab, Pakistan	26	100	9.79	86±2.01	28	Iqbal et al. (2021)
5	Labeo *rohita*		30	100	6.84	90	16.3	
6	*Labeo bata*	India	30	100	6.91	89	16	Mohapatra et al. (2016)
7	*Cirrhinus mrigala*		30	100	7	92	17	
8	*Catla catla*	India	28.5	100	11	85	27	Chaturvedi et al. (2015)
9	*Labeo rohita*		28	100	6.88	85	24	
10	*Cirrhinus mrigala*	Bangladesh	28	100	7.34	88	26	Mondol et al. (2014)
11	*Labeo bata*		28	88	7.55	77	27	
12	*Puntius pulchellus*	New Delhi India	26	80	14	74	48	Sridhar et al. (2014)
13	*Labeo rohita*		29	100	7.14	82	22	
14	*Cirrhinus mrigala*	Punjab, Pakistan	29	100	7.88	86	24	Khan et al. (2013)
15	*Catla catla*		29	100	8.2	77	26.3	
	Labeo	Barisal,	29	100	7.2	86	24.5	Minar et al.

	rohita	Bangladesh						(2012)
	Cirrhinus mrigala		29	100	7.90	88	26	
	Catla catla		29	100	8.45	76	27	
16	*Labeo rohita*	Punjab, India	28	100	7.56	77	24.3	Tiwana and Raman (2012)
17	*Cirrhinus mrigala*	India	26	100	9	91	27.2	Rokad et al. (2006)
18	*Labeo victorianus*	*Uganda*	24	100	10.43	69	34	Rutaisire and Booth 2004

Effect of Temperature on the Reproductive Performance of Exotic Species

Shddoud et al. (2023), conducted breeding experiments on *C. idella* and *C. carpio* to assess the efficacy of the dopamine antagonist method. Experiments were carried out in Syria's Masab Fish Hatchery in July 2022. The experimental sets consisted of 9 sets that received both domperidone and carp pituitary extract, while the control sets included the remaining 9 sets that received only CPE treatment. The ovulation ratio, fecundity, fertilization rate, and hatching rate of the control sets were all 92.85%, 355172 eggs/kg, 73% and 55%, respectively. In the experimental sets, hatching took place between 20 hours and 45 minutes and 21 hours after fertilization, whereas in the control sets at 26-26.5°C, hatching took place between 20 hours and 45 minutes and 21 hours. Body weight was found to positively affect absolute fecundity (r = 0.98, 0.99) and relative fecundity (0.97, 0.97), respectively, in experimental sets and control sets. Similarly, Sharif et al. (2022) conducted an induced breeding experiment on common carp at the Banchte fish hatchery in Jashore to investigate the efficacy of dry and wet pituitary glands. The first dose of hormone was injected into female and male brood fish with wet and dry P.G. doses of 0.7 mg PG/kg. Female brooders received the second dose of 3 mg PG/kg. After 7 hours of the second injection, brood fish were ready to spawn. At a 20°C average water temperature, 13 hours are required for the spawning of common carp. The fertilized eggs of *C. carpio* were allowed to undergo incubation for a period of 48 hours at an ambient water temperature of approximately 20°C, following which they successfully hatched. Fertilization rates were almost 86% and 91% for wet and dry PG hormones, respectively. For wet and dry pituitary gland hormones, the rates of fertilization were calculated at 86% and 91%, respectively. The hatching rates were 85%. In Pakistan, scientific researchers kept brooders in the circular tank for spawning after hormonal administration. In both species, the ovulation rate was 100 percent. Variation in water temperature from 22 to 28 °C and spawning responses were seen in *H. nobilis and C. carpio* after latency periods of (8.8±0.1-10.84±0.02 hours) and (8.1±0.26-9.8±0.01 hours), respectively. At water temperatures between 22 and 28°C, *H. nobilis* showed a fertilization rate of (61-73%) while *C. carpio* showed a fertilization rate of (60-76%). The degree-hours to hatching were calculated as (748-784) and (682-702) respectively, at water temperatures ranging from 22 to 28 °C. Degree-hours to spawning were determined to be 215.6 and 226.4 for *C. carpio* and *H. nobilis*, respectively. *H. nobilis* hatching rate was calculated as 52-70%, while *C. carpio* was 56-71%. With an increase in water temperature up to a certain point, the rates of fertilization and hatching generally increase. With the help of these results, future spawning predictions for the fish *C. carpio* and *H. nobilis* can be made (Azhar et al. 2022).

Felix et al. (2021), concluded that HCG and Ovatide were applied in the current study to induce the breeding of the endemic barb, *Dawkinsia filamentosa*, at various doses (0.3, 0.5, 0.7, and 0.9 ml/kg). All artificial hormones performed well at 0.7 ml/kg body weight. The colour of fertilized eggs had a hint of orange and was golden. Hatching occurred 34-36 hours at 26°C after fertilization. From egg to adulthood, the entire developmental stage of *D. filamentosa* was documented in captivity. After hatching, the yolk sac remained for up to 60 hours. The current study contributes to the introduction of valuable native fish, *D. filamentosa* hatchery seeds, into the ornamental fish trade. The presence of

hatchery seed may lessen the exploitation of wild resources and aid in their preservation. Similarly, Hayat et al. (2020), analyzed a study to check the effect of different dosages of ovaprim hormones on carnivorous fish on the *R. rita during the* end of July 2015 in circular breeding tanks at Chashma Barrage, Mianwali, Pakistan. Female's brooders were treated with ovaprim dosages of 0.5 ml/kg, 0.8 ml/kg, and 1 ml/kg, which resulted in ovulation of 0%, 100%, and 100%, respectively. Males of (*R. rita*) were treated with a dose of 0.4 mL/kg in all cases. At a temperature of 27-29 °C, there was a 70% fertilization rate and a 58% hatching rate within 20-25 hours.

In Nepal, Yadav et al. (2019), performed a breeding experiment on silver carp by using Ovaprim hormone at the Fish Development and Training Centre in Janakpur Dham, Nepal. The current field study was conducted from May 2019 to August 2019 for 4 months in order to examine the physico-chemical variables, biology of silver carp, fecundity, fertility rate, hatching rate, embryonic development, and fingerling growth. The successful spawning of silver carp occurred after two successive doses of Ovaprim. For females, the first dose is 2 g/kg, and the second dose is 4 g/kg. When a female receives her second dose of 3 g/kg of body weight, a male receives a single dose. The latency period varied from 810 to 900 minutes. Dissolved oxygen levels were 5.0-8.2 mg/l, and cobalt levels were 13-17.1 mg/l. A total of 324,996 to 606,800 eggs were spawned, with a fertility rate of 72.592.5%, a G.S.I. of 16.21 to 24.44, and a hatching rate of 65.21 to 82.60 percent in silver carp. After three hours, the embryo's development was observed. The embryo's development was continued, and it takes 18 to 20 hours for the egg to hatch. After being transferred to nursery ponds after five days of hatching, the fry was regularly fed artificially formulated feed containing 35-40% feed. Szabó et al. (2019), investigated that the biggest yearly production in freshwater aquaculture is produced by Chinese carp, namely silver carp, bighead carp, and grass carp, at water temperatures ranging from 22 to 26°C. These species geographic ranges were expanded via induced breeding, which also made seed supplies more dependable. At a large-scale hatchery, Chinese carp were artificially bred over 18 spawning seasons, and the effectiveness of this process was evaluated over time. In addition, we examined the PGSI and the ovulation ratio in connection to the three different weight categories for females (small, medium, and big). Through the 18 spawning seasons, 555 silver carp, 300 bighead carp, and 1175 grass carp females were selected for reproduction. The majority of silver carp brooders chosen were in the 4-7 kg weight range. The ovulation ratios of grass carp (79.1%), bighead (77.3%), and silver carp (80.9%) were comparable. In comparison to silver carp (10.5 4.8%) and bighead carp (10.1 3.96%), grass carp (9.3 4.26%) had a substantially lower mean PGSI. In the different weight classes of silver carp and bighead carp, there were no discernible differences in the ovulation ratios and mean PGSI values. In Pakistan, Urooj et al. (2018), concluded a work to investigate the spawning response of grass carp and silver carp through induced breeding at Punjab Fish Seed Hatchery Islamabad, Pakistan. Experimental research was conducted in a circular tank. Brooders were selected, and ovaprim hormone was injected intramuscularly. They showed successful spawning, fertilization, and hatching. Silver carp required 247-269 degree-hours for successful spawning within 8.45 hours at a temperature range of 24-28.5ºC, while grass carp required 219.4-232.5 degree-hours for complete spawning at a temperature range of 24-28.5ºC. The fertilization rate of 80.8% was observed in grass carp, while in silver carp it was 76.9%.

Mahadevi et al. (2018), scrutinized an experiment on telescopic eye goldfish (*Carassius auratus*) through induced breeding by using a synthetic hormone (WOVA-FH) in Chennai, India, at a temperature range of 24-30 °C. This study was performed during the period from January to March for 3 months. Females were induced by administering two doses, while males were injecting a single dose of hormone during the injection of the female. WOVA-FH at doses of 0.7 mL/kg and 1.4 mL/kg was observed to be effective for males and females, respectively. Latency period was observed at 5-9 hours, fertilization rate was 46-74%, and hatching rate was 52-82%. Hosain et al. (2015), conducted a breeding experiment on black carp by using synthetic hormones (Ovaprim) and pituitary hormones for the induction of spawning. For PG, two doses were injected at the rate of 2 mg/kg for females and 6 mg/kg for males, while males received a single dose at the rate of 2 mg/kg of body weight. For Ovaprim, the male and female were injected only one dose at a rate of 0.3 ml/kg for the male and 0.25 ml/kg for the female. Following the administration of the injection, observations revealed that the

spawning cycle lasted for a duration of 12 hours in the group receiving the pituitary gland injection and 11 hours in the group injected with Ovaprim, while maintaining a temperature of 23°C in the aquatic environment. This finding suggests a significant impact of the type of hormone treatment received on the timing of spawning activity. A total of 23 kg of female black carp were subjected to two treatments, resulting in the successful acquisition of 6 kg of hatchling. In Iran, Vazirzadeh et al. (2014), explored the stimulatory effect on doctor fish (*Garra rufa*) at an ornamental fish hatchery (El Nino) located in Marvdasht, Fars, Iran, by induced breeding through the synthetic hormone ovaprim. The experiment was divided into five groups. Groups 2 to 5 were treated with 0.1, 0.2, 0.02, and 0.04 ml/kg of ovaprim per fish. Groups 2 and 3 were treated with a high dose of ovaprim, resulting in 100% mortality. The temperature range during the experiment was 24-26°C When the temperature was increased to 28°C, fish started to spawn subsequently. Malik et al. (2014), looked at the fish hatchery in Chillya Thatta, Pakistan, and researchers looked at the ovulation and hatching rates of Koi carp in cement tanks. The experiment was performed during the month of March. Twelve males and six females were selected for induced breeding at 20-24 ºC. The average weight for females and males was measured with an electronic balance of 536.7±6g and 759±8 g, respectively. The brooder was injected with ovaprim hormone at 0.2 ml/kg and 0.5 ml/kg for male and female, respectively, and held in a cement tank (3×6×5 feet) afterwards. The results revealed a 100% ovulation rate, and fertilization and hatching rates were 75.2% and 83.3%, respectively.

Chezik et al. (2013), determined degree days for fish growth and development, including selecting the threshold temperature for fish growth. Through an examination of data derived from eight distinct species of fish and 86 disparate aqueous environments situated throughout the North American continent, an analysis was conducted that revealed an extensive array of water temperature values that exhibited a significant influence on the overall variability in the growth rates of the observed fish populations. The growth and development of fish are impacted by the prevailing water temperature. The present investigation yields the finding that there is a positive correlation between water temperature reduction and a prolonged latency period, characterized by increased development time. 18 degrees Celsius is the minimum threshold temperature for fish growth. In Africa Gadissa and Devi (2013), explored a study on African catfish (*Clarias gariepinus*) to evaluate the spawning response by induced breeding at a fisheries research center south of Addis Ababa in the mid-rift valley of Ethiopia. Brooders were held in concrete ponds with a size of 7x5x1 m with continuous flow of water and a replacement system. Brooders were injected with pituitary solution intramuscularly at a dose of 3 mg/kg body weight to stimulate breeding. Spawning occurred within 13.5 hours after the latency period at a temperature of 23 ºC. Hatching occurred within 33 hours. Hatchability and fertility rate were not significant.

Rahman et al. (2013), analyzed an experiment on stinging catfish (*Heteropneustes fossilis*) in Jessore districts of Bangladesh. The environmental condition was 27 ºC. They performed this experiment to check the comparison efficiency of two inducing agents, such as pituitary gland extract (PGE) and human (HCG). They injected PGE into brooders at 8 mg/kg and 2 mg/kg, female and male, respectively. In another experiment, they injected ovaprim at 0.5 mL/kg and 0.1 mL/kg according to the body weight of males and females, respectively. They injected HCG into female and male fish brooder with a range of 1000 IU/kg body weight. This study shows that the ovaprim hormone has maximum efficiency as compared to other inducing agents. In ovaprim, the ovulation period was 10 hours for successful spawning, while in PGE and HCG, spawning occurred within 15 hours. Gadissa and Devi (2013) explored a study on African catfish (*C. gariepinus*) to evaluate the spawning response by induced breeding at a fisheries research center south of Addis Ababa in the mid-rift valley of Ethiopia. Brooders were held in concrete ponds with a size of 7x5x1 m with continuous flow of water and a replacement system. Brooders were injected with pituitary solution intramuscularly at a dose of 3 mg/kg body weight to stimulate breeding. Spawning occurred within 13.5 hours after the latency period at a temperature of 23 ºC. Hatching occurred within 33 hours. Hatchability and fertility rate were not significant. Similarly, Santos et al. (2013), examined an endangered fish from the Brazilian basin of the So Francisco River called *Lophiosilurus alexandri*. The purpose of this study was to cause *L. alexandri* to spawn in order to gather information on the species' various reproductive parameters.

Adults were given *C. carpio* pituitary homogenate (CPH) to induce spawning. 8.4 hours after the second dose of CPH, the oocytes were stripped while the water temperature was kept at 26°C. 75% of them, showed a positive therapeutic response. The mean oocyte diameter was 3.1± 0.2 mm before hydration and 3.6±0.2 mm after hydration, respectively, and there was 74±0.5 stripped oocytes per gramme of ova. The oocytes had a gelatinous coating and were opaque, yellowish, demersal, and extremely adhesive. The larvae hatched up to 56 hours after fertilization, and they were 8.4 mm in length overall. Overall oocyte fecundity was 4,534,671, with a 59% fertilization rate. Initially and eventually, 2,631 and 1,542 embryos were fertilized respectively. Important biological data about *L. alexandri* is provided by this work, which can be applied to the management and conservation of this species.

In Nigeria, a study on African Mud Catfish (*C. gariepinus*) through induced breeding by using ovaprim in the laboratory of the Department of Zoology, University of Ilorin, Nigeria. 18 females and 7 males brooders were acclimatized for 3 weeks in a separate concrete pond. They required 11.30-27.50 hours for the latency period at a water temperature of 24°C. The fertilization rate was observed at 88.70%, 87.58%, 77.38%, 0%, and 0%. Hatchability rate was 56.38%, 54.07%, 57.75%, 0%, and 0%. It has been determined that ovaprim diluted in normal saline at a level of 50% inclusion will encourage reproduction in *Clarias gariepinus* and be extremely successful in responding (Olumuji and Mustapha 2012). Mahmud et al. (2011), assessed a research experiment on goldfish (*Carassius auratus*) at Khulna University, Bangladesh. They performed this study to observe embryonic and larval development through induced spawning. They injected ovaprim hormone into females with a double dose and males with a single dose of 0.5 ml/kg, 0.7 ml/kg, 0.1 ml/kg, and 1.2 ml/kg regarding their body weight. Ovulation occurs within 6 hours at a temperature range of 18-22°C. With different hormone dosages, the rate of fertilization of eggs was 50%, 51.47%, 47.30%, and 48.24%. With identical dosages, the hatching rate was seen to be 44.35%, 43.7%, 39.83%, and 36.08%. At a water temperature of 15 to 18°C, all eggs hatched in around 48 hours. Phelps et al. (2011), conducted an experimental investigation employing LH-RHa 20 g/kg at Auburn University's Fisheries and Allied Aquacultures department on hybrid catfish-induced breeding. In 100-litre aquariums, brooder females were kept at 24, 26, and 28 °C. Female ovulation rates were reported to be 52.9%, 82.4%, and 95.5%, respectively. Females began to ovulate between 58 and 64 hours at 24°C, 48 to 52 hours at 26°C, and 24 to 40 hours at 28°C, respectively, requiring degree-hour response times of 1405, 1141, and 951(degree-hours).

In Pakistan, experimental research was done to investigate the induced spawning, fecundity, fertilization rate, and hatching rate of grass carps through induced breeding by using ovaprim in Faisalabad, Pakistan. 22 brooders were selected for induced spawning. Female brooders received 0.6 ml/kg, and male brooders received 0.2 ml/kg intramuscularly injected into the caudal fin of fish. The experiment was performed in a circular tank with a diameter of 2m. Spawning occurred within 8.30 hours at a temperature range of 26-30°C after hormonal administration. The fertilisation rate was 80.36%. After fertilisation, hatching occurred within 18-22 hours. The hatching rate was about 79.49% (Muhammad et al. 2011). Similarly, Molla et al. (2008), reported research work on the breeding of catfish through introduced breeding through pituitary extract at Agricultural University, Mymensingh. Mature brooders with a weight of 600-1250 g were selected for induced breeding. Fish were injected with pituitary gland extract at different doses to induce spawning in females and male brooders. Incubation was conducted at 23-24 °C, with PG doses affecting 0%, 100%, 100%, and 100% ovulation. The incubated eggs started to hatch within 23-25 hours.

Marimuthu et al. (2008), performed an experiment to investigate the efficacy of the ovatide hormone snakehead in Tamil Nadu, India. 9 females and 18 males were selected for induced breeding. Spawning occurred within the range of 23-27 hours at a temperature of 24°C. Hatching occurred within 82.6%, 91.6%, and 90%, respectively. Brooders were administered with ovatide hormones of 0.2, 0.4, and 0.6 ml/kg, respectively. Incomplete spawning was noticed when hormone 0.2 mL/kg was injected. Successful spawning was observed at a medium dosage of 0.4 ml/kg. The hatching period ranged from 23.5 to 27.6 hours at a water temperature of 29°C. Similarly, Phelps et al. (2007), have verified a research experiment to determine fertilization rate by induced breeding. A female channel

catfish, mated with, a male blue catfish. When artificial fertilization and induced spawning were combined, the results were mixed. The hormone is injected into the fish body at the intramuscular junction after ovulation, when eggs reach maturity. Brood females were held at different temperatures, such as 24 ºC, 26 ºC, and 28 ºC, in 100 L aquaria. Hormone 20 ug/kg of LH-RHa was injected. After 12 hours, a second dose of 100 ug/kg of hormone was injected. When the first eggs were released or by the stripping process, the hourly time was recorded. Eggs are fertilized with milt and incubated. The ovulation rate varies due to differences in temperature in the environment. Female brooders showed ovulation with a percent of 52.9%, 82.4%, and 95% at temperatures of 24°C, 26°C, and 28°C, respectively. Degree-hours required for response time are 1405±117, 1411±238 and 951±261 respectively. Marimuthu et al. (2007), evaluated an experimental study on fish (*C. striatus)* to check the efficacy of ovatide hormones at different dosages by induced breeding. They selected mature 9 males and 18 females for induced breeding. Their body weight range was 750-900 g. Brooders were administered with ovatide hormones of 0.2, 0.4, and 0.6 ml/kg, respectively. Incomplete spawning was noticed when hormone 0.2 mL/kg was injected. Successful spawning was observed at a medium dosage of 0.4 ml/kg. The latency period was 23-27 hours at 27±1.5ºC. In Cairo Elgamal (2006), analyzed an experiment on the sliver carp *H. molitrix* to investigate the latency period at Waddy El-Natron, Cairo. Each group contained eight brooders, and they were to breed at a temperature range of 25.5 ºC. Pituitary powder was injected according to weight and gender. For group 1, a delay duration of 206.4 degree-hours (about 8 h) was recorded; for groups II and III, the latency periods were 7.8 and 7.9 hours, respectively. This study demonstrates that injection time in silver carp is a significant issue. When a hypophysation approach was used, the natural latency duration in silver carps was 188 (degree-hours). The presence of males with spawning females increases their reaction to hormone treatment and reduces their latency time by around 24 minutes (199.6 degree-hours).

In India, a work was performed to determine the effect of ovaprim hormone with different dosages on spotted murrel and catfish by inducing spawning in Tamil Nadu, India. They injected fish brooders with synthetic hormones like ovaprim and HCG regarding their body weight at a temperature of 27-29 ºC. They injected hormones with varying dosages for successful spawning in *H. fossilis.* Different dosages of hormones, i.e., 0.3 ml/kg, 0.5 ml/kg, and 0.7 ml/kg, gave successful results for spawning in spotted murrel. The latency period was 28-24 hours in spotted murrel after the administration of hormones. Similarly, Arabeci et al. (2001), performed an induced breeding experiment on common carp by using the Ovaprim hormone to determine the effect of temperature on latency period. In order to induce spawning in the common carp under standard hatchery conditions, 20 g/kg LHRH was injected along with 0.7 mg/kg of the Dopa antagonist. Ovulation was successful as a result of this therapy. The minimum latency in common carp given LHRH injections was 14 hours. The latency period was temperature-dependent. Identical spawning was produced by LHRH with the same latency. Results suggested that fish farmers may successfully manage their hatcheries by forecasting latency at a specific temperature. Tucker (1994), reviewed the most recent knowledge on serranid fish spawning in captivity. Because of their significance as food or decorative fish, the Serranidae family has been the subject of much research. Currently, the milkfish *C. chanos* is induced to spawn by injecting pituitary homogenate and human chorionic gonadotropin, then manually removing the hydrated eggs. Due to this method, vital broodstock is lost, fertilization rates are poor, and the timing of spawning is uncertain. It is crucial to have a dependable way to trigger spawning. This study examined the ovulatory and spawning properties of LHRH-a. Approximately 48 or 24 hours after application, respectively. As many as 31 species have had their ovaries artificially stimulated, whereas at least 23 species were breeding spontaneously in confinement. The majority of voluntary spawning has occurred with well-fed, sparsely populated fish during the natural breeding season, under conditions of ambient temperature and partial or total natural light. Species-specific temperature ranges are preferred for spawning, and for serranids, the length of the day seems to be a less important trigger than temperature.

Pepin et al. (1991), investigate the impact of temperature and size on the development and survival rates of pelagic marine fish. Models factoring in temperature and size explain 30-81% of vital rate variation. Temperature rises were generally correlated with higher rates of daily development and

mortality. The incidence of mortality during the egg's early life stages did not demonstrate any discernible effect with respect to size, whether calculated on a daily or cumulative basis. The present study provides evidence that mortality rates during early life stages were not impacted by physical size, implying that other factors may play a greater role in determining the risks of mortality within this population. Temperature affected egg and yolk-sac larvae mortality rates equally but oppositely. Size affects fish mortality rates. Shorten the text (reduce its length). Compensating for temperature effects can reduce environmental uncertainty's impact on survival rates. This study suggests using temperature and size to assess the effects of the environment on fry. Ros et al. (1984), performed an experimental study in which male and female *Rhamdi sapo* were given intraperitoneal injections of pituitary solutions from the characin *Prochilodus platensis* at dosages ranging from 0.37 to 6 mg dry weight per kg of body weight. Ovulation was successfully induced at doses between 0.75 and 6.0 mg/kg. For females kept at various temperatures, 17 to 27°C, the latent interval between injection and ovulation decreased with rising temperature. For the highest hatching rates, the time between ovulation and stripping dropped from around 9 hours at 20°C to 5 hours at 24°C. In samples collected after 15 hours at 20°C or 8 hours at 24°C, no viable eggs were still present. Similar work Tang (1964), found that mature striped mullets might be coaxed to spawn by the injection of hormone ingredients during their spawning journey to the southwest coast of Taiwan, according to preliminary results from a series of tests carried out during the striped mullet fishing season of 1963. The dosage required to trigger ovulation in female mullets was roughly equivalent to two pituitaries from fish of the same species and size combined with 40 units of Synahorin, a gonadotropin-containing supplement made from a combination of chorionic gonadotropin and hypophysial extract. Photomicrographs of living specimens are used in this work to explain and illustrate the embryonic development of this species as seen from its exterior characteristics. These eggs were hatched in 59 to 64 hours at temperatures in the water that ranged from 20 to 24.0°C. In shallow water or in aquariums, holding boxes were used to maintain newly hatched larvae. None of these larvae made it through the prelarval stage; the bulk perished two days after hatching (Table 2).

Table 2. Effect of water temperature on the reproductive performance of exotic species of Pakistan.

Sr.	Species Name	Experiment Site	Aver. Temp (ºC)	Ovulation rate	Spawning time (hours)	Fertilization rate (%)	Hatching time (h)	Ref.
1	*Ctenopharyngodon idella*	Syria	26.5	100	8.55	67	24.6	de Oliveira et al. (2023)
2	*Cyprinus carpio*		26.5	92	8.22	88	26.2	
3	*Cyprinus carpio*	Bangladesh	20	78	13	86	30.8	Sharif et al. (2022)
4	*Hypophthalmichthys nobilis*	Islamabad, Pakistan	26	86	8.44	71	25.3	Azhar et al. (2022)
5	*Cyprinus carpio*	India	26	90	8.56	76	25.44	
6	*Dawkinsia filamentosa*		26	100	16	65	36	Felix et al. (2021)
7	*Rita rita*	Mianwali, Pakistan	28	100	9.45	70	25	Hayat et al. (2020)
8	*Hypophthalmichthys molitrix*	Dham, Nepal	27	100	8.45	82	20	Yadav et al. (2019)
9	*Hypophthalmichthys molitrix*	*Hungary*	23	80.9	9.55	61	28.49	Szabó et al. (2019)
10	*Ctenopharyngodon*		23	79.1	9.18	56	29.34	

	idella							
11	*Hypophthalmichthys nobilis*	Islamabad, Pakistan	23	77.3	10.76	69	30.20	Urooj et al. (2018)
12	*Ctenopharyngodon idella*		26.4	82	8.45	67	25 26	
13	*Hypophthalmichthys molitrix*		26.4	78	9.00	59		
14	*Carassius auratus*	Chennai, India	27	100	9.00	82	24	Mahadevi et al. (2018)
15	*Mylopharyngodon piceus*		23	42	11	53	30	Hosain et al. (2015)
16	*Garra rufa*	Fars, Iran	28	62	10	46	26	Vazirzadeh et al. (2014)
17	*Cyprinus rubrofuscus*	Thatta, Pakistan	22	100	16	75.2	78	Malik et al. (2014)
18	*Clarias gariepinus*	Ethiopia	23	100	13.5	64	33	Gadissa and Devi (2013)
19	*Heteropneustes fossilis*	Bangladesh	27.1	100	10	74	15	Rahman et al. (2013)
20	*Lophiosilurus alexandri*	*Brazil*	26	75	8.4	59	56	Santos et al. (2013)
21	*Clarias gariepinus*	Nigeria	24	82.6	11.3	87	32	Olumuji and Mustapha (2012)
22	*Carassius auratus*	Bangladesh	20	77.5	6	51	42	Mahmud et al. (2011)
23	*Clarias macrocephalu*	Auburn, USA	26	82.4	16	38	29	Phelps et al. (2011)
24	*Ctenopharyngodon idella*	Faisalabad, Pakistan	28	100	8.30	80.36	21	Muhammad et al. (2011)
25	*Clarias gariepinus*	Bangladesh	24	63.7	11	67	24	Molla et al. (2008)
26	*Channa striata*	India	24	77.2	13	73	29	Marimuthu et al. (2008)
27	*Ictalurus furcatus*	Auburn, USA	26	52.9	7	82.4	54.3	Phelps et al. (2007)
28	*Hypophthalmichthys molitrix*	Cairo	25	100	8	76.3	28	Elgamal (2006)
29	*Cyprinus carpio*	*Turkey*	22	84.4	14	66.4	32	Arabeci et al. (2001)

CONCLUSION

Water temperature has a direct effect on fish reproduction. Raising the water temperature progressively improves embryonic development and breeding efficiency to the ideal level. Excessive heat over the optimal threshold thinned the egg shells and caused early hatching of eggs that died before the yolk sac was absorbed. There is non-linear or practically zero spawning and hatching activity when the water

temperature falls below the lower threshold. This study may shed light on how water temperature affects fish-induced spawning, fertilization rate, and egg hatching. The farmers would be able to approve the technology's potential degree of performance in circumstances like the availability of brood stock and adequate environmental parameters like temperature.

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