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# Koi Fish (*Cyprinus rubrofuscus* Lacepede, 1803) Breeding Techniques at the Center for Freshwater Aquaculture (BBPBAT) Sukabumi, West Java

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**ABSTRACT**

One of the economically valuable aspects of fisheries development is ornamental fish farming. Koi farming has advantages as the fish can easily adapt to various environments. The breeding activities included broodstock maintenance, spawning and nursery tank preparation, broodstock selection, hormone injection, egg hatching, larva care, nursery stages, and harvesting. This research is intended to help the author learn and understand proper koi fish breeding techniques at the Center for Freshwater Aquaculture (BBPBAT) in Sukabumi, West Java. The data collected during this research activity includes both primary and secondary data. Primary data is obtained directly without intermediaries, resulting in raw data. Secondary data, on the other hand, is gathered through intermediaries or indirectly, and is sourced from library reports and information from governmental institutions. In the koi fish breeding activities carried out, it was observed that the koi fish had a fecundity rate of 71,400 eggs, a FR (Fertilization Rate) of 92%, a HR (Hatching Rate) of 97%, a SR (Survival Rate) in Nursery Phase I of 45%, and in Nursery Phase II of 74%.

## INTRODUCTION

Indonesia is a country with great potential for the development of the fisheries sector. One of the economically valuable aspects of fisheries development is ornamental fish farming (Tran *et al*., 2017). Over recent years, many people have started keeping various types of ornamental fish, and interest in these fish has been growing across all levels of society. The demand for ornamental fish commodities is substantial. One of the most popular freshwater ornamental fish commodities with high market value internationally is the koi fish (*Cyprinus rubrofuscus*) (Aries *et al*., 2022).

Koi fish originated in Japan and have experienced rapid development in Indonesia due to their variety of beautiful colors and patterns. Koi farming has advantages as the fish can easily adapt to various environments (Andriska, 2016). The significant potential of koi fish (*Cyprinus rubrofuscus*) has attracted various parties to further develop this commodity. The high commercial value and trade of koi fish in Indonesia have prompted the government, through the Ministry of Marine Affairs and Fisheries (KKP), to establish koi production centers.

This development is expected to improve the quality of local koi fish so that they can compete with imported koi fish in both domestic and international markets (Anwar, 2015).

However, the high market demand for koi fish has not yet been met optimally. This is due to several production challenges, such as high mortality rates due to poor adaptation to aquaculture environments, slow growth of koi larvae, and suboptimal farming practices. A lack of experience and knowledge in aquaculture activities has led to decreased productivity of these cultured species. Based on the above considerations, this research is intended to help the author learn and understand proper koi fish breeding techniques at the Center for Freshwater Aquaculture (BBPBAT) in Sukabumi, West Java.

## METHODS

### Time and Place of Research

This research was conducted from March 10 to June 16, 2023, at the Center for Freshwater Aquaculture, Selabatu Village, Cikole District, Sukabumi City, West Java.

### Data Collection Techniques

The data collected during this research activity includes both primary and secondary data. Primary data is obtained directly without intermediaries, resulting in raw data. Secondary data, on the other hand, is gathered through intermediaries or indirectly, and is sourced from library reports and information from governmental institutions. In addition to primary data, secondary data is also essential for obtaining broader information. Primary data can be collected directly from the main source through methods such as:

### Observation

Observations in this research are made on various aspects related to koi fish farming, including monitoring and recording all feeding activities and observing best techniques in koi aquaculture.

### Active Participation

Active participation involves engaging in all field activities related to koi farming, including preparation and the entire farming process.

### Interview

Interviews are conducted by directly questioning sources, informants, or staff at the Center for Freshwater Aquaculture in Sukabumi, West Java.

The primary data to be collected in this research includes:

### Absolute Length and Weight Growth

Absolute length growth is used to calculate the increase in length of the farmed koi fish during maintenance by finding the difference between the final body length and the initial body length. Absolute length growth is calculated using the formula (Effendie, 1997):

$$\mathbf{Lm = L_t - L_0}$$

Where:

Lm = Absolute length growth (cm)
Lt = Total length at the end of maintenance (cm)
L0 = Total length at the start of maintenance (cm)

Absolute weight growth is used to calculate the increase in the weight of the koi fish seeds during maintenance by finding the difference between the average weight at the end and at the start of the maintenance period. Absolute weight growth is calculated with the formula:

$$\mathbf{Wm = W_t - W_0}$$

Where:
Wm = Absolute weight growth (g)
Wt = Total weight at the start of maintenance (g)
W0 = Total weight at the end of maintenance (g)

**Specific Growth Rate (SGR)**

The specific growth rate represents the percentage difference between the final and initial weights, divided by the maintenance period. SGR can be calculated using the formula (Hariati, 1989):

$$SGR = \frac{W_t - W_0}{t} \times 100\%$$

Where:
SGR = Daily Growth Rate (%)
Wt = Average weight at the end of maintenance (g)
W0 = Average weight at the start of maintenance (g)
t = Duration of maintenance (days)

**Fecundity**

Fecundity = Total Egg Weight × Number of Sample Eggs

**Fertilization**

The Fertilization Rate (FR) is the calculation of the total number of fertilized eggs in fertilization practices, using the following formula:

**% FR = (∑ Fertilized Eggs × 100%) ÷ ∑ Total Eggs**

**Hatching Rate (HR)**

The Hatching Rate (HR) calculates the total number of hatched eggs in hatching practices, with the following formula:

**% HR= (∑ Hatched Eggs × 100%) ÷ ∑ Fertilized Eggs**

**Survival Rate (SR)**

Survival Rate (SR) is the percentage of koi fish that survive during the maintenance period. Survival rate is calculated with the formula (Effendie, 2002):

$$SR = \frac{N_t}{N_0} \times 100\%$$

Where:
SR = Survival rate (%)

Nt = Number of surviving fish at the end of maintenance
N0 = Number of fish alive at the start of maintenance

**Feed Conversion Ratio (FCR)**

Feed efficiency is measured at the end of the maintenance period using the following formula (Effendi, 1997):

$$FCR = \frac{F}{(Wt+D)-Wo}$$

Where:
W0 = Biomass weight at the start of research (g)
Wt = Biomass weight at the end of research (g)
D = Biomass weight of fish that died during the study (g)
F = Weight of feed given during the study (g)

**Water Quality**

Water quality in the pond is crucial to successful koi fish farming. Water quality is influenced by various chemicals dissolved in the water, such as dissolved oxygen (DO), pH, temperature, and other physical substances. In koi farming, water quality needs to be monitored, including measurements of temperature, pH, DO, $CO_2$, $NO_2$, and $NO_3$. Measurements are conducted in the Water Quality Laboratory at BBPBAT Sukabumi.

**Data Analysis**

The data collected during the research activities are analyzed using descriptive and statistical techniques. Descriptive analysis provides a detailed account of all activities conducted, supported by a literature review to ensure clear information. Statistical tests are performed both manually and using Microsoft Excel.

## RESULTS

The following are the data from the results of this research.

Table 1. Fecundity Value

| Total Egg Weight | Sample Egg Weight | Number of Sample Eggs | Fecundity (Eggs) |
|---|---|---|---|
| 300 g | 1.13 g | 238 | 71,400 |

Table 2. The Fertilization Rate of Koi Fish

| Fertilized Eggs | Sample Eggs | FR (%) |
|---|---|---|
| 220 | 238 | 92 |

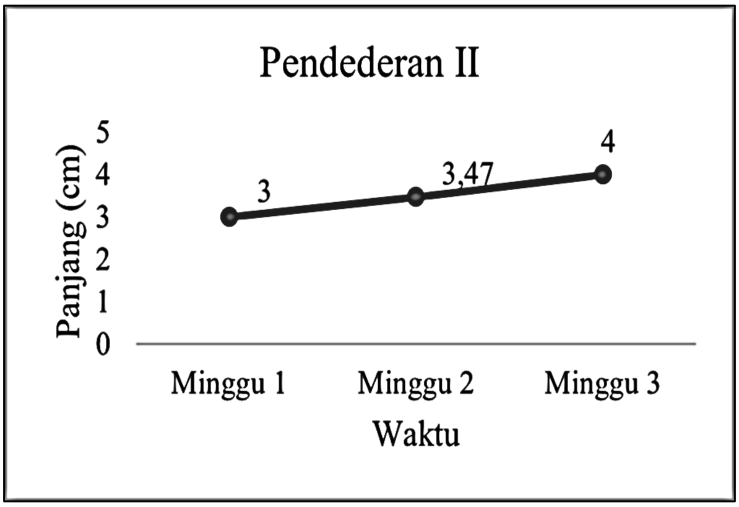
Table 3 The Hatching Rate of Koi Fish

| Hatched Eggs | Fertilized Eggs | HR (%) |
|---|---|---|
| 215 | 220 | 97 |

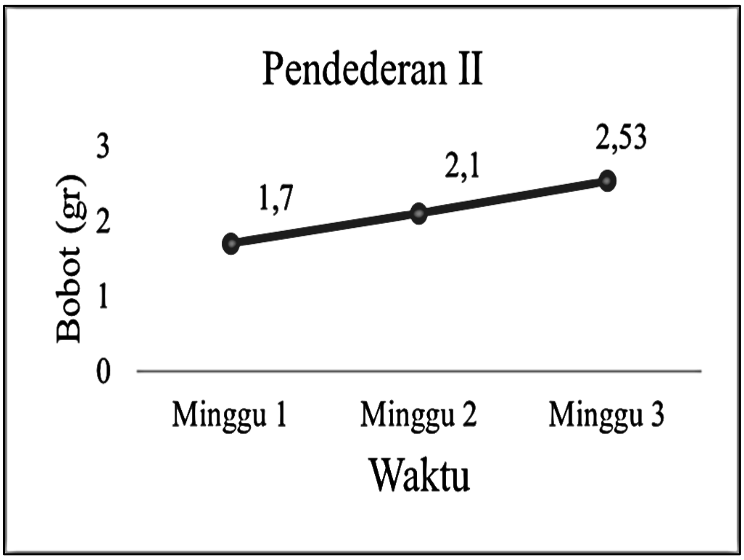
Table 4. Water Quality Measurements

| No | Water Quality Parameter | Male Broodstock Pond | Female Broodstock Pond | Spawning Tank | Nursery Pond I | Nursery Pond II |
|---|---|---|---|---|---|---|
| 1 | Temperature (°C) | 24.7 | 24.9 | 24.3 | 25.3 | 24.8 |

| No | Water Quality Parameter | Male Broodstock Pond | Female Broodstock Pond | Spawning Tank | Nursery Pond I | Nursery Pond II |
|---|---|---|---|---|---|---|
| 2 | pH | 6.84 | 6.86 | 6.37 | 7.29 | 8.91 |
| 3 | DO (mg/L) | 3.68 | 5.04 | 4.34 | 5.24 | 7.94 |
| 4 | $CO_2$ (mg/L) | 106.93 | 25 | 59.5 | 25.87 | 55.19 |
| 5 | $NO_2$ (mg/L) | 0.33 | 0.196 | 0.196 | 0.192 | 0.177 |



Graph 1. Length Growth of Koi Fish in Nursery Phase II



Graph 2. Weight Growth of Koi Fish in Nursery Phase II

## DISCUSSION

### Broodstock Maintenance

### Broodstock Maintenance Ponds

The procurement of high-quality broodstock is a key component in koi fish breeding, as quality offspring come from quality broodstock, making broodstock maintenance crucial (Torsabo *et al.*, 2024). During maintenance, ponds are used as a holding space for the broodstock. At BBPBAT Sukabumi, the koi varieties cultivated include Kohaku, Showa, Sanke, Benigoi, Ogon, Platinum, Shusui, Bekko, Tancho, and others. There are four broodstock maintenance ponds, located in Block B and the Showroom. Male and female koi are kept in separate ponds to facilitate broodstock selection and prevent natural or unwanted spawning. This aligns with Berlinsky *et al.* (2020), who states that broodstock maintenance aims to enable selection and gonad maturation for breeding, with males and females kept separate to avoid mass spawning.

**Broodstock Feeding**

Broodstock are fed twice daily, in the morning at 8:00 AM and in the afternoon at 3:00 PM. The feed used at BBPBAT Sukabumi is a floating commercial feed with a 5 mm diameter, containing 35% crude protein, 5% crude fat, 3% crude fiber, 12% crude ash, 12% moisture, and 2% calcium.

The protein content in the feed given to the broodstock at BBPBAT Sukabumi meets the nutritional standards for koi broodstock, aligning with Hendriana (2021), who emphasizes that protein is a crucial nutrient for broodstock due to its nitrogen content, with an optimal range of 30-35% for koi broodstock

**Koi Fish Spawning**

Spawning is the process of releasing eggs by the female and sperm by the male, followed by fertilization (Kholodnyy et al., 2020). This stage is vital for the life cycle and species survival. In koi fish, spawning behavior involves the male persistently chasing and nudging the female, typically occurring at night and completing by morning (Roos, 2016). The female releases eggs, and the male releases sperm to fertilize them. At BBPBAT Sukabumi, semi-natural spawning is conducted, with broodstock placed in a ratio of 1 female to 3 males due to the males' smaller size relative to the females.

**Preparation of Spawning and Nursery Tanks**

Spawning preparation begins with setting up a suitable tank for the process. The spawning tank is a rectangular fiberglass tank measuring 4 m × 2 m × 1 m with a water depth of 80 cm. Preparing the spawning tank involves thoroughly cleaning the tank's surface of any debris by scrubbing with a brush or sponge and rinsing with flowing water until all dirt is cleared through the outlet pipe. A hapa net is installed, and the tank is filled with water. The hapa is used to facilitate egg collection and provide a substrate for egg attachment. The hapa is a fine white net measuring 2 m × 3 m, secured by tying its ends to the corners of the fiberglass tank. After the hapa is installed, the tank is filled with water to a depth of 80 cm, and aeration is provided at three points for oxygen supply. Kakaban mats are then placed in the tank, serving as substrates for koi eggs and creating a secluded area to avoid disturbing the fish during spawning. Two types of kakaban are used: floating and sinking, with three floating and five sinking kakaban mats, to suit koi eggs that either float or sink to the tank bottom.

The nursery pond preparation is carried out 3-4 days before the larvae are released. The nursery pond is a permanent structure with cement walls and a cement bottom. Preparation includes cleaning the pond, drying it for about two days to eliminate bacteria and pathogens, adding six bags of manure as fertilizer per pond, and cleaning and checking the water channels, pits, and canals. Finally, the pond is filled with water.

Water quality management at BBPBAT involves measuring parameters such as temperature, pH, dissolved oxygen (DO), $CO_2$, and $NO_2$. Water samples are collected directly from the maintenance ponds and placed into sample bottles. The water quality tests are conducted in the BBPBAT Water Quality Laboratory, assisted by a lab technician. Water quality data can be seen in Table 4.

**Broodstock Selection**

Broodstock selection is performed before the spawning process, typically around 10:00 a.m. During field practice, three categories of selection were implemented at BBPBAT Sukabumi: size selection, variety selection, and gonadal maturity selection. Female broodstock used were 1.5-2 years old with a minimum weight of 2 kg, while male broodstock were 8 months old with a weight of at least 0.5 kg (Standard Operating Procedure BBPBAT Sukabumi). Gender differentiation can be done by pressing the belly toward the tail; a white liquid indicates a male. Characteristics of a female ready for spawning include slow movement, a distended and soft belly, and a slightly protruding, reddish anus.

**Broodstock Injection**

During the spawning process at BBPBAT Sukabumi, semi-artificial spawning was carried out by injecting the hormone Ovaprim into female koi broodstock. The female was weighed beforehand to determine the hormone dosage. In this instance, the broodstock weighed 1.7 kg, so 0.9 ml of Ovaprim was administered, following the dosage of 0.5 ml/kg. Ovaprim, a combination of salmon gonadotropin-releasing hormone analog (GnRH) and anti-dopamine, stimulates gonadotropin hormones in fish, promoting faster ovulation and spawning.

The injection was administered at 2:00 p.m., with the hormone injected near the base of the female's tail. The broodstock were then placed in the spawning tank with the male introduced shortly after. Spawning occurred early in the morning around 2:00 a.m., and the fish were removed from the tank at 7:00 a.m. the next day. The female was weighed again post-spawning to determine gonadal weight.

**Egg Counting and Hatching**

Egg hatching can be done by either transferring the koi broodstock or moving the egg-laden kakaban to the egg incubation tank. During field practice, the method used involved moving the broodstock so that the spawning tank could be immediately repurposed as an incubation tank.

To calculate gonadal weight, the initial weight of the female broodstock was subtracted from her post-spawning weight. The gonadal weight obtained was 300 grams, with a sample weight of 1.13 grams, resulting in a count of 238 eggs. The fecundity for a 300 g egg weight was 71,400 eggs, which is very high. According to Aries *et al*. (2022), the average fecundity for koi is around 50,000 eggs per kg of broodstock weight.

The fertilization rate was calculated by subtracting the number of unfertilized eggs from the total number of sampled eggs. Fertilized eggs appear clear, while unfertilized eggs are milky white. Fertilized eggs are left for 24-36 hours with aeration. The hatching rate (HR) can be determined after the eggs hatch uniformly. The hatching rate calculation was done on a sample of eggs on a sieve, resulting in a hatching rate of 97%. Hatchability is influenced by factors such as egg quality, sperm nutrition, and external factors such as DO, pH, temperature, and ammonia (Salamon, 2020).

Based on the table, the temperature in the male broodstock pond is 24.7°C, in the female broodstock pond is 24.9°C, in the spawning tank is 24.3°C, in Nursery Pond I is 25.3°C, and in Nursery Pond II is 24.8°C. The temperatures recorded in each pond and tank are optimal for koi fish survival, aligning with Andrian (2024), who stated that the ideal temperature range for koi aquaculture is 24-26°C. Temperature plays a crucial role in fish growth, affecting metabolism, digestive enzymes, and growth hormones. According to Killen (2014), metabolic rate, growth, and energy expenditure are significantly influenced by water temperature . Lower temperatures reduce appetite and metabolic rate, while higher temperatures support growth up to an optimal point.

According to Satriawan (2023), the optimal pH range for koi fish maintenance is 6.5-8.5. The pH values in the male broodstock pond, female broodstock pond, spawning tank, and Nursery Pond I fall within this optimal range. However, the pH value in Nursery Pond II is 8.91, slightly above the optimal range, which could inhibit fish growth.

According to Rosiana (2017), dissolved oxygen (DO) is oxygen gas bound within water molecules, essential for aquatic organisms in the respiratory process. Each fish's DO consumption varies based on species, age, activity, and physiology. The DO values recorded were 3.68 mg/L in the male broodstock pond, 5.04 mg/L in the female broodstock pond, 4.34 mg/L in the spawning tank, 5.24 mg/L in Nursery Pond I, and 7.94 mg/L in Nursery Pond II.

Carbon dioxide is highly soluble in water, and its concentration in aquatic ecosystems is a parameter closely linked to pH. Higher $CO_2$ concentrations generally correspond to lower pH levels. The $CO_2$ measurements were 106.93 mg/L in the male broodstock pond, 25 mg/L in the female broodstock pond, 59.5 mg/L in the spawning tank, 25.87 mg/L in Nursery Pond I, and 55.19 mg/L in Nursery Pond II.

The chemical parameters of koi ponds, specifically nitrite ($NO_2$) and nitrate ($NO_3$), were also measured. The nitrite values were 0.33 mg/L in the male broodstock pond, 0.196 mg/L in the female broodstock pond, 0.196 mg/L in the spawning tank, 0.192 mg/L in Nursery Pond I, and 0.177 mg/L in Nursery Pond II. These nitrite levels are relatively high, with a maximum allowable concentration of 0.2 mg/L in water, aligning with Sa'adati (2022), who stated that nitrite levels should ideally range between 0.1-0.5 mg/L in aquatic environments.

## CONCLUSION

The breeding activities included broodstock maintenance, spawning and nursery tank preparation, broodstock selection, hormone injection, egg hatching, larva care, nursery stages, and harvesting. In the koi fish breeding activities carried out, it was observed that the koi fish had a fecundity rate of 71,400 eggs, an FR (Fertilization Rate) of 92%, an HR (Hatching Rate) of 97%, an SR (Survival Rate) in Nursery Phase I of 45%, and in Nursery Phase II of 74%.

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