Growth performance of Java barb, *Barbonymus gonionotus*, in relation with water temperature

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Abstract. The Java barb (*Barbonymus gonionotus*) is a native species of Indonesia, believed to exhibit sensitivity to fluctuations in environmental temperature. This study aimed to investigate the effects of varying temperature conditions on the growth performance, oxygen consumption, and survival of Java barb fries. Throughout a 42-day experimental period, the fish were exposed to different temperature regimes, and their growth, oxygen consumption, and survival metrics were closely monitored. The results indicated that temperature significantly impacted the growth performance of Java barb fries, while showing no discernible effect on their survival rates. The optimal temperature range for both growth and survival of Java barb fries falls between 31.12 and 32.9°C. This research emphasizes the importance of considering optimal temperature conditions in the cultivation of Java barb to promote growth and enhance survival rates.
Key Words: *Barbonymus gonionotus*, fish survival, growth performance, oxygen consumption, temperature.

Introduction. The Java barb (*Barbonymus gonionotus*) is a native fish species and plays an important economic role in Indonesia. Locally is known as Tawes (Budiharjo 2001; Hanief et al 2014; Jasmine & Begum 2016; Faradiana et al 2018; Abdan & Sulistiono 2023). The Java barb is a herbivorous fish species that has been traditionally farmed in freshwater facilities across Indonesia (Subandiyono et al 2018; Abdan & Sulistiono 2023; Budiantoro & Noor 2023). Due to factors such as the introduction of other fish species, changes in habitat, and global warming, the wild populations of Java barb have started to decline (Budiharjo 2001; Nugroho et al 2012; Buwono et al 2019). Therefore, it is crucial to develop hatcheries for the cultivation and restocking of Java barb in their natural environment. However, one significant challenge in Java barb seed production is the low survival rates, particularly in Central Java, Indonesia (Nugroho et al 2012). This issue persists because the optimal water temperature requirements for the farmed fish's survival have not yet been determined.

As a critical environmental factor in aquaculture, water temperature exerts profound effects on various aspects of fish physiology, including muscle growth and collagen metabolism (Lin et al 2022; Mazumder et al 2024). It influences fish health, metabolic rate, and oxygen demand (Wedemeyer et al 1999). Additionally, global climate change is expected to alter environmental temperatures (Solomon et al 2007; Isaak & Rieman 2013), further impacting aquatic ecosystems. The ambient temperature plays a pivotal role in regulating physiological processes such as metabolism and fish growth (Hastuti et al 2003; Lin et al 2022; Abdan & Sulistiono 2023). Given that fish are poikilothermic animals, they are highly susceptible to changes in water temperature (Coulter 2015; Sánchez-Nuño et al 2019; Mazumder et al 2024). This sensitivity directly influences metabolic processes, growth, reproduction, and collagen deposition in muscles (López-Olmeda & Sánchez-Vázquez 2011; Lin et al 2022). Seasonal variations in water temperature serve as natural stressors for fish worldwide, impacting their growth performance and metabolism (Brandt et al 2022). Exposure to low temperatures can suppress the activity of antioxidant enzymes, disrupt the glutathione redox cycle, and decrease glutathione levels (Sánchez-Nuño et al 2019). In response to temperature fluctuations, fish employ various adaptive mechanisms, including the synthesis of heat shock proteins, aimed at increasing tolerance and protecting cells from heat-induced damage or other stressors (Lindquist 1986, as cited in Thomas 1990). However, this response comes at the expense of reduced protein synthesis critical for growth, ultimately disrupting the fish's growth process (Hastuti et al 2003).

The Java barb is notably sensitive to fluctuations in ambient temperature. Drawing upon this information, a comprehensive study was conducted to investigate the impact of water temperature on the growth performance of Java barb. The objective of this study was to assess how variations in water temperature influence key parameters including growth rate, feed intake, feed conversion efficiency, oxygen consumption, and survival rates of Java barb.

Material and Method

Experimental fish and methods of rearing. Java barb with a total amount of 552 fries were reared on June-August 2023. The body length of all the fries selected varied between 2 and 3 cm, with the body weight between 0.19 and 0.22 g. Then, these fish were kept in 12-aquaria measuring 50 x 30 x 30 cm, with a stocking density of 2 fish per liter of water (Rachimi et al 2014) or 46 fries per aquarium for 42 days. To fill the aquarium, 23 liters of water were used. During the rearing period, the test fish were fed a commercial diet known as type 781-1 (Subandiyono et al 2018). This diet had a minimum crude protein content of 30.05% and was ground into fine particles before being fed to the fish. The fish were fed using the at-satiation feeding method three times a day at 08:00 am, 14:00 pm, and 20:00 pm (Hanief et al 2014).

Experimental design. The experiment utilized a completely randomized design (CRD). The research conducted a total of 4 treatments, with 3 replicates each. The experimental fish were raised at different water temperatures for 42 days: 28°C (treatment A), 30°C (treatment B), 32°C (treatment C), and 34°C (treatment D). A water heater and thermostat were used to maintain the desired temperatures.

Measured variables

a. Total feed consumption. According to Subandiyono & Hastuti (2016), the total feed consumption (TFC) can be determined using the following formula:

$$TFC = F1 + F2 + \cdots + Fn$$

where: TFC = total feed consumption (g);
F1 = weight of feed consumed on the 1st day (g);
F2 = weight of feed consumed on the 2nd day (g);
Fn = weight of feed consumed on the nth day (g).

b. Feed utilization efficiency. As per Hastuti & Subandiyono (2020), the feed utilization efficiency (FUE) can be determined using the following formula:

$$FUE\ (\%) = \frac{Wt - W0}{F} \times 100$$

where: FUE = feed utilization efficiency (%);
Wt = total weight of fish at the end of the study (g);
Wo = total weight of fish at the beginning of the study (g);
F = amount of feed consumed during the study (g).

c. Absolute length gain. The calculation of absolute length gain can be executed utilizing the subsequent formula (Hastuti & Subandiyono 2018):

$$AbL = Lt - L0$$

where: AbL = absolute length gain (cm);
Lt = body length at the end of the study (cm);
L0 = body length at the beginning of the study (cm).

d. Absolute weight gain. The computation of absolute weight gain can be calculated using the subsequent formula (Hastuti & Subandiyono 2016):

$$AbW = Wt - W0$$

where: AbW = absolute weight gain (g);
Wt = fish weight at the end of the rearing period (g);
W0 = fish weight at the beginning of the rearing period (g).

e. Specific growth rate. The specific growth rate can be determined utilizing the subsequent formula (Hastuti & Subandiyono 2016):

$$SGR\ (\%\ day^{-1}) = \frac{LnWt - LnW0}{t} \times 100$$

where: SGR = specific growth rate (% day^{-1});
LnWt = Ln of the body weight at the end of the study (g);
LnWo = Ln of the body weight at the beginning of the study (g);
t = rearing period (days).

f. Fish survival rate. The calculation of fish survival can be performed using the following formula (Subandiyono & Hastuti 2016):

$$SR\ (\%) = \frac{Nt}{N0} \times 100$$

where: SR = survival rate (%);
Nt = number of fish at the end of the study;
N0 = number of fish at the onset of the study.

g. Oxygen consumption rate. The determination of the oxygen consumption rate in Java barb utilized the method of Fry (1957). This method employs a closed container system to monitor oxygen levels hourly. Specifically, each container, holding 13 liters of water and equipped with a thermostat, accommodated 10 test fish. Subsequently, the containers were sealed tightly, with only a small aperture for the insertion of the dissolved oxygen (DO) meter HI 9147. DO levels within each container were then recorded hourly over a 4-hour observation period. The collected DO data were subsequently employed to compute the oxygen consumption rate. As per Das et al (2018), the oxygen consumption rate was calculated by the following formula:

$$OCR\ (mg\ O_2\ fish^{-1}\ h^{-1}) = \left[\frac{(Oi\ -\ Of)\ x\ V}{(T\ x\ N)}\right]$$

where: OCR = the oxygen consumption rate of an individual fish (mg O_2 $fish^{-1}$ $hour^{-1}$);
Oi = the initial dissolved oxygen concentration (mg O_2 L^{-1});
Of = the dissolved oxygen concentration at the end of the measurement (mg O_2 L^{-1});
V = the volume of water (L);
T = the duration of the measurement (hours);
N = the number of fish under observation.

h. Water quality. In the culture vessel, water quality was assessed through monitoring key parameters such as pH, DO, and total ammonia nitrogen (TAN). The water temperature was set as the treatment level required. Temperature readings were recorded daily, while measurements for TAN, pH, and DO were conducted weekly for each treatment. DO and temperature were assessed using the HI 9147 DO meter, while pH levels were determined with the Lutron-208 pH meter. The concentration of TAN was determined using the MAPADA V-1100D spectrophotometer.

Data analysis. An analysis of variance (ANOVA) was conducted on a dataset comprising feed consumption levels, feed efficiency, specific growth rate, length growth, weight growth, and survival rates. The purpose was to assess the impact of water temperature on the feed consumption, feed utilization efficiency, and the fish growth. Subsequently, if the ANOVA yielded statistically significant results ($p < 0.05$), Duncan's test was employed to further elucidate any discernible differences between treatments. Additionally, a descriptive analysis of water quality data was undertaken.

Results. Table 1 displays the experimental data encompassing various parameters such as fish body weight, body length, growth in length and weight, feed consumption and efficiency, and survival rates of Java barb, influenced by water temperature. The study involved Java barb fries with an average initial body weight of the trials ranging from 0.19 g to 0.20 g, reared over a period of 42 days within a temperature range of 28 to 34ºC. Significant variations in weight gain were observed among the fish ($p < 0.05$), with the absolute weight gains ranging from 0.75 to 1.48 g (Table 1). The average initial weight of the experimental fish remained consistent, ranging between 0.19 and 0.20 g at the onset of the trial. However, notable disparities in fish weight were observed by the conclusion of the experiment (Table 1). Notably, the highest fish weight was recorded in the treatment group exposed to a temperature of 32°C, reaching 1.68±0.07 g, while fish subjected to 34°C exhibited a lower average weight of 1.52±0.23 g.

Table 1

Growth performance of Java barb according to water temperature

Parameters	*Water temperature*			
	28ºC	*30ºC*	*32ºC*	*34ºC*
Initial body weight (g fish^{-1})	0.20±0.01^{a}	0.20±0.02^{a}	0.20±0.02^{a}	0.19±0.01^{a}
Final body weight (g fish^{-1})	0.94±0.01^{a}	1.33±0.12^{b}	1.68±0.07^{c}	1.52±0.23^{bc}
Initial body length (cm fish^{-1})	2.61±0.05^{a}	2.61±0.09^{a}	2.62±0.05^{a}	2.62±0.03^{a}
Final body length (cm fish^{-1})	4.1±0.08	4.54±0.20	5.03±0.06	4.89±0.19
Absolute length gain (AbL, cm)	1.49±0,10^{a}	1.93±0.13^{b}	2.41±0.08^{c}	2.26±0.21^{c}
Total feed consumption (TFC, g)	51.94±3.68^{a}	67.70±2.30^{b}	86.87±5.54^{c}	88.41±2.51^{c}
Feed utilization efficiency (FUE, %)	66.13±4.06^{a}	76.66±5.04^{b}	78.85±8.17^{b}	69.15±10.76^{a}
Absolute weight gain (AbW, g)	0.75±0.01^{a}	1.13±0.11^{b}	1.48±0.08^{c}	1.33±0.22^{bc}
Specific growth rate (SGR, % day^{-1})	3.75±0.05^{a}	4.54±0.16^{b}	5.11±0.28^{c}	4.93±0.27^{bc}
Fish survival rate (SR, %)	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}

Note: The same superscript on the same row indicates values that are not significantly different ($p > 0.05$)

Figure 1 provides a visual representation of the body weight dynamics of Java barb during the culture period.

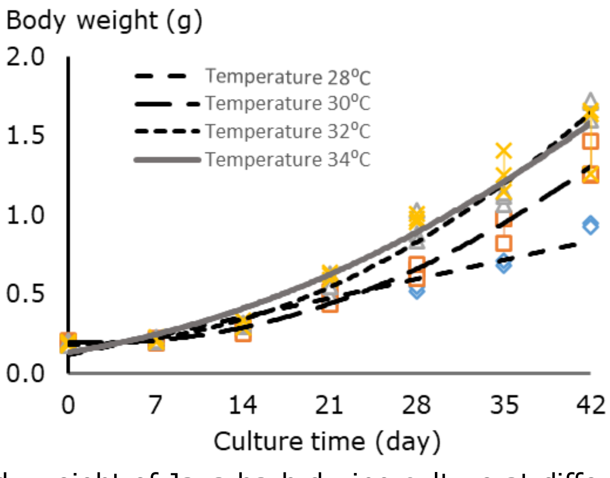
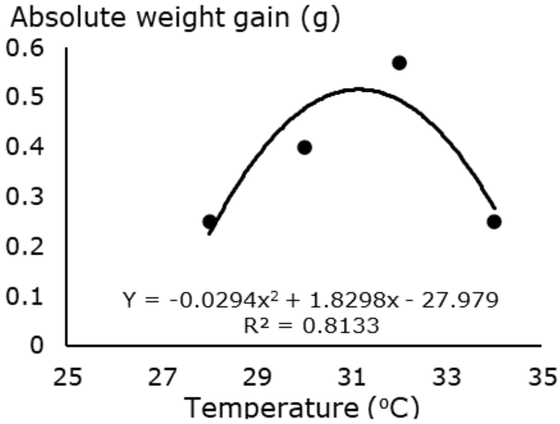


Figure 1. Body weight of Java barb during culture at different temperatures.

The relationship between temperature and both weight and length gains of the fish over the 42-day cultivation period is elucidated in Figure 2.



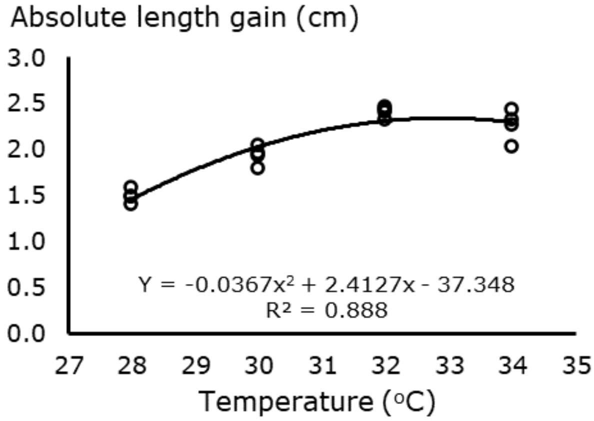


Figure 2. The illustration of the relationship between weight gain (g) and length gain (cm) of Java barb with cultivation temperature.

Figure 3 illustrates the oxygen consumption of Java barb reared at different temperature levels. The graph depicts a quadratic relationship between oxygen consumption and temperature, as indicated by the equation $Y = -0.0251x^2 + 1.5849x - 23.616$, where Y represents oxygen consumption and X represents temperature. The coefficient of determination (R^2) for this relationship was calculated to be 0.8264, suggesting a strong correlation between temperature and oxygen consumption.

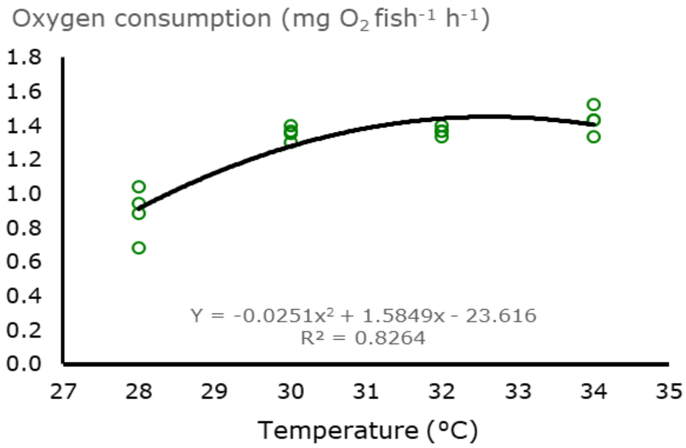


Figure 3. Oxygen consumption of Java barb at various levels of water temperature.

Table 2 displays the measurements of dissolved oxygen, pH, and total ammonia nitrogen (TAN) levels obtained during the cultivation of Java barb.

Table 2

Dissolved oxygen values, pH, and ammonia in the water medium of Java barb cultivated at different temperatures

Temperature treatments (ºC)	*DO (mg L^{-1})*	*pH*	*TAN (mg L^{-1})*
28	5.0-6.6	7.8-8.5	0.157-0.207
30	5.2-6.6	7.8-8.5	0.156-0.203
32	5.2-6.6	7.9-8.5	0.155-0.207
34	5.3-6.6	7.9-8.5	0.163-0.208
Optimal values	> 3[(a)]	6.5-8.5[(b)]	< 1[(c)]

[a)] Trang et al (2017), El-Sayed (2002), Syed et al (2022); [b)] Stone et al (2013), Ani et al (2022), Budiantoro & Noor 2023; [C)] Harwanto et al (2011).

The data presented indicates that the water quality conditions in the cultivation medium, including DO, pH, and ammonia levels, are conducive to supporting fish life.

Discussion. The Java barb demonstrates remarkable thermal resilience, exhibiting tolerance across a broad spectrum of temperatures. However, deviations from its optimal temperature range can precipitate adverse consequences, particularly concerning its growth dynamics. Research indicates that when water temperatures stray below or exceed the preferred range, growth rates of the Java barb may experience notable diminishment. Notably, within the range of 28 to 34ºC, the species can sustain its vitality, showcasing a commendable 100% survival rate, as corroborated by empirical data (Table 1). Extended exposure to temperatures beyond the designated optimal range poses significant physiological challenges for the Java barb. Such stressors are known to instigate multifaceted repercussions, including compromised immune functionality and attenuated growth rates (Brandt et al 2022; Mazumder et al 2024; Tian et al 2024). It is imperative to acknowledge the susceptibility of this species to environmental thermal fluctuations, as informed management strategies are pivotal for safeguarding its welfare and promoting sustainable aquaculture practices.

The temperature of water utilized in fish farming operations significantly influences feed intake levels. Java barb, when cultivated in environments characterized by elevated temperatures (specifically ranging from 28 to 34ºC), demonstrates heightened feed consumption rates (Table 1). These empirical findings underscore a clear and direct correlation between temperature elevation within the aquaculture milieu and the subsequent augmentation in feed consumption. As ambient temperatures escalate within the aquaculture setting, a concomitant increase in feed intake becomes apparent. This observation aligns with the research insights of Budiantoro & Noor (2023) and Searle et al (2024), who emphasized the distinctive temperature tolerances exhibited by various fish species. Each species inherently gravitates towards an optimal temperature range conducive to its physiological well-being. Consequently, understanding and managing temperature dynamics in aquaculture systems emerge as pivotal factors in promoting optimal feeding practices and ensuring the overall health and productivity of fish populations.

An escalation in temperature elicits an augmented metabolic rate in fish, necessitating additional energy derived from increased feed consumption (López-Olmeda & Sánchez-Vázquez 2011; Tian et al 2024). The gradual ascent in temperature, ranging from 28 to 32ºC, precipitates a corresponding elevation in feed intake, a trend supported by statistical significance ($p < 0.05$). However, when the temperature surpasses 32ºC and reaches 34ºC, no substantial disparity in feed consumption is observed. This phenomenon is attributed to the limited stomach capacity inherent in Java barb, constraining further feed intake. A parallel pattern is discernible in the efficiency of feed utilization. Notably, a significant enhancement in feed utilization efficiency is evident ($p < 0.05$) with the temperature increment from 28 to 30ºC. Furthermore, this efficiency remains comparable between 30 and 32ºC. However, should temperatures persist in rising to 34ºC, a decline in the efficiency of utilizing consumed feed ensues. The energy content within the feed assumes critical significance in supporting the heightened metabolic demands (Mazumder et al 2024). This assertion aligns with the findings of Subandiyono et al (2018), suggesting that adequate feeding under optimal environmental conditions adequately meets the energy requirements for fish maintenance and growth. Subandiyono & Hastuti (2016) reinforce this notion, elucidating that energy derives from consumed feed, subsequently transforming into gross energy within the fish's body. Approximately 80% of the total energy intake by the fish is allocated towards growth and various metabolic functions (Tian et al 2024).

In environments characterized by warmer water, fish exhibit heightened feed consumption, driven by the imperative need for additional energy to sustain accelerated metabolic processes (Mazumder et al 2024; Searle et al 2024; Tian et al 2024). The elevation in metabolic rate, intricately influenced by the optimal temperature range for fish species, serves as a primary catalyst for the observed surge in feed intake. Walberg (2011) and Huo et al (2017) validated that fish, as poikilothermic organisms, undergo dynamic metabolic adaptations in response to temperature fluctuations. Moreover, the impact of optimal temperature extends beyond mere metabolic rate modulation, influencing the activity of digestive enzymes crucial for both catabolic and anabolic processes. This interplay between temperature and enzyme function contributes significantly to the physiological state of fish, notably amplifying their appetite. Killen (2014) concurs with this perspective, elucidating that elevated temperatures prompt an increase in fish metabolism, compelling a commensurate rise in feed consumption to fulfill heightened energy requirements. The observed correlation between feed consumption rate and water temperature escalation (Table 1), further underscores the intricate interplay between temperature dynamics and fish feeding behavior.

The research findings indicate that Java barb cultured in environments characterized by higher water temperatures exhibit notable increases in both body weight and body length (Figure 1 and Figure 2). Consequently, it is evident that elevated cultivation medium temperatures correspond to enhanced fish growth, underlining the profound influence of temperature on this vital aspect of piscine development ($p < 0.05$). Notably, within the temperature range of 28 to 32°C, the growth trajectory of Java barb experiences augmentation, reaching its pinnacle at 32°C. However, as temperatures rise further to 34°C, a discernible decline in Java barb growth becomes apparent. The positive impact of elevated water temperatures on both feed consumption and growth rate is contingent upon the fish remaining within their optimal temperature range. However, straying from this optimal range can precipitate adverse consequences, potentially impeding growth, reproduction, and even resulting in fish mortality (Ramee et al 2020; Abdan & Sulistiono 2023). Exceeding optimal temperatures necessitates increased energy and nutrient expenditure for maintenance, thereby diminishing the proportion allocated to growth, as elucidated by Watanabe & Kiron (1994). Morales-Marín et al (2019) provided further credence to these observations, underscoring the significant influence of environmental temperature on various facets of fish physiology, encompassing growth dynamics, metabolic rates, and oxygen consumption. Additionally, temperature exerts a noteworthy impact on muscle growth and collagen metabolism (Lin et al 2022). Sun et al (2019) and Mazumder et al (2024) further expounded on this, highlighting the metabolic alterations induced by warmer temperatures in fish species.

The weight gain and length gain of Java barb exhibit a positive correlation with the water temperature of the cultivation medium (Figure 2). The relationship between weight gain and temperature is modeled by the equation $Y = -0.0294x^2 + 1.8298x - 27.979$, yielding an R^2 value of 0.8133. Similarly, the relationship between length gain and temperature is expressed by the equation $Y = -0.0367x^2 + 2.4127x - 37.348$, with an R^2 value of 0.888. From these equations, the optimal temperature for maximizing weight gain is determined to be approximately 31.12°C, while for length gain, it is approximately 32.9°C. These calculated optimal temperatures signify the temperature thresholds at which Java barb fish exhibit the highest rates of weight and length gain within the cultivated environment.

The oxygen consumption rate of Java barb demonstrates a notable increase with ascending temperature (Figure 3). This relationship between temperature and oxygen consumption in Java barb is aptly captured by the equation $Y = -0.0251x^2 + 1.5849X - 23.616$, boasting a coefficient of determination (R^2) of 0.8264. Through extrapolation from this equation, the optimal temperature for Java barb cultivation is estimated to be approximately 31.57°C. Moreover, the robust association between temperature and oxygen consumption in Java barb underscores the pivotal role of temperature adaptation as a fundamental physiological phenomenon in fish species. These findings resonate with earlier studies conducted on common carp (*Cyprinus carpio*) fry (Chatterjee et al 2004) and pangasius catfish (*Pangasius pangasius*) fry (Debnath et al 2006), further corroborating the significance of temperature-mediated adaptations across various aquatic organisms.

The temperature span of 28 to 34°C emerges as a viable and conducive range for Java barb, as evidenced by a robust 100% survival rate observed during cultivation within this thermal spectrum (Table 1). Concurrently, throughout the cultivation period, critical water quality parameters such as DO, pH, and TAN maintain optimal levels (Table

2). Notably, the DO concentration observed throughout the Java barb cultivation period remains consistently within the range of 5.0 to 6.6 mg L^{-1}, aligning with established ideal thresholds (Trang et al 2017; El-Sayed 2002; Syed et al 2022; Budiantoro & Noor 2023). Likewise, pH levels ranging from 7.8 to 8.5 are indicative of favorable conditions for fish survival (Stone et al 2013; Ani et al 2022; Budiantoro & Noor 2023). Furthermore, the TAN levels, maintaining a range of 0.155 to 0.208 mg L^{-1}, fall comfortably within the optimal range conducive to fish life (Harwanto et al 2011).

The optimal temperature range varies significantly among distinct fish species and is further nuanced by various reproductive stages, encompassing embryos, larvae, fry, and adults (Souchon & Tissot 2012). Higher temperatures have a propensity to accelerate fish metabolism, thereby optimizing the functionality of enzymes and growth hormones (Ridwantara et al 2019; Mazumder et al 2024). The present study examining the effect of temperature on the survival rate of Java barb underscores that the survival rate remains unaltered across different treatment temperatures. With a consistent survival rate value of 100% observed across all treatments, it is indicative that the temperatures employed fall comfortably within the tolerance range for Java barb. Consequently, the responses pertaining to feed intake, growth, and feed utilization efficiency are notably influenced by temperature fluctuations that remain within acceptable limits.

The ability of fish to survive is intricately linked to their capacity to adapt to prevailing environmental conditions. A high survival rate not only signifies resilience but also underscores the efficacy of adaptation to each treatment condition. Under favorable environmental circumstances, fish not only endure but also flourish, benefiting from optimal conditions conducive to growth and vitality. These observations align with the findings of Huwoyon & Kusmini (2010), who stated that fish growth is intrinsically linked to their adaptness in acclimating to their surroundings. Highlighting the significance of temperature, Ayyubi et al (2019) underscored how unsuitable temperatures can profoundly impact the survival of Java barb. Furthermore, Syafei (2017) and Hastuti & Subandiyono (2016) provided comprehensive insights into the multifaceted influence of temperature on various aspects of fish life, encompassing survival, growth, swimming abilities, reproduction, migration patterns, and overall development. This collective body of research underscores the pivotal role of temperature in shaping the ecological dynamics and physiological well-being of aquatic organisms.

Conclusions. The research findings unequivocally highlight the profound impact of temperature fluctuations on the growth trajectory of Java barb (*Barbonymus gonionotus*) fry. Remarkably, despite these fluctuations, there appears to be no discernible effect on their survival rates. Through meticulous analysis, the temperature range deemed optimal for both robust growth and sustained survival is identified to fall between 31.12 and 32.9°C.

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Conflict of interest. The authors declare that there is no conflict of interest.

References

Abdan M., Sulistiono, 2023 Growth patterns and reproductive aspect of naleh (*Barbonymus* sp.) in Krueng Lanca, Nagan Raya Regency, Aceh Province. IOP Conference Series: Earth and Environmental Science 1221(1):012014.

Ani J. S., Manyala J. O., Masese F. O., Fitzsimmons K., 2022 Effect of stocking density on growth performance of monosex Nile tilapia (*Oreochromis niloticus*) in the aquaponic system integrated with lettuce (*Lactuca sativa*). Aquaculture and Fisheries 7(3):328-335.
Ayyubi H., Budiharjo A., Sugiyarto, 2019 [Morphological characteristics of silver barb fish population *Barbonymus gonionotus* (Bleeker, 1849) from different waters locations in Central Java Province]. Jurnal Iktiologi Indonesia 19(1):65-78. [in Indonesian]
Brandt C., Groening L., Klassen C., Anderson W. G., 2022 Effects of rearing temperature on yolksac volume and growth rate in lake sturgeon, *A. fulvescens*, from hatch to age-1. Aquaculture 546:737352.
Budiantoro A., Noor H., 2023 Identification of fish species in Kuning River, Sleman Regency, Yogyakarta Special Region. IOP Conference Series: Earth and Environmental Science 1147(1):012015.
Budiharjo A., 2001 [Displacement of morphological characters of *Barbodes gonionotus* at Serpeng Cave Lake, Gunungkidul]. Biodiversitas 2(1):104-109. [in Indonesian]
Buwono N. R., Arfiati D., Arifin M. S., 2019 [Analysis of silver barb (*Barbonymus gonionotus*) gut content in Bengawan Solo River estuary, Lamongan Regency]. Journal of Aquaculture and Fish Health 8(1):8-14. [in Indonesian]
Chatterjee N., Pal A. K., Manush S. M., Das T., Mukherjee S. C., 2004 Thermal tolerance and oxygen consumption of *Labeo rohita* and *Cyprinus carpio* early fingerlings acclimated to three different temperatures. Journal of Thermal Biology 29(6):265-270.
Coulter P. D., 2015 Consequences of short-term water temperature variability to fish: current and future climate change impacts. PhD dissertation, Purdue University, India, 164 pp.
Das S. K., Noor N. M., Kai K. S., Juan Q. Z., Iskandar N. S. M., De M., 2018 Effects of temperature on the growth, gastric emptying time, and oxygen consumption rate of mahseer (*Tor tambroides*) under laboratory conditions. Aquaculture Reports 12(1): 20-24.
Debnath D., Pal A. K., Sahu N. P., Baruah K., Yengkokpam S., Das T., Manush S., 2006 Thermal tolerance and metabolic activity of yellowtail catfish *Pangasius pangasius* (Hamilton) advanced fingerlings with emphasis on their culture potential. Aquaculture 258(1-2):606-610.
El-Sayed A. F. M., 2002 Effects of stocking density and feeding levels on growth and feed efficiency of Nile tilapia (*Oreochromis niloticus* L.) fry. Aquaculture Research 33(8): 621-626.
Faradiana R., Budiharjo A., Sugiyarto S., 2018 [Biodiversity of fishes in Mulur Reservoir Sukoharjo, Central Java, Indonesia]. Depik: Jurnal Ilmu-Ilmu Perairan, Pesisir dan Perikanan 7(2):151-163. [in Indonesian]
Fry H. F. J., 1957 The aquatic respiration of fish. In: The physiology of fishes. Vol. 1: Metabolism. Brown M. E. (ed), Academic Press Inc. Publishers, New York, pp. 1-63.
Hanief M. A. R., Subandiyono S., Pinandoyo, 2014 [The effect of feeding frequencies on the growth and survival rate of Java barb juveniles (*Puntius javanicus*)]. Journal of Aquaculture Management and Technology 3(4):67-74. [in Indonesian]
Harwanto D., Oh S. Y., Jo J. Y., 2011 Comparison of the nitrification efficiencies of three biofilter media in a freshwater system. Fisheries and Aquatic Sciences 14(4):363-369.
Hastuti S., Subandiyono S., 2016 Application of biofloc technology in intensive farming affected production and blood performances of the catfish [*Clarias gariepinus* (Burchell, 1822)]. Jurnal Teknologi 78(4-2):221-226.
Hastuti S., Subandiyono S., 2018 Hematological parameters of the North African catfish *Clarias gariepinus* farmed using biofloc technology. AACL Bioflux 11(4):1415-1424.
Hastuti S., Subandiyono S., 2020 Blood serum biochemistry responses and digestive enzyme activities of tilapia (*Oreochromis niloticus*) according to different dietary protein level consumption. AACL Bioflux 13(6):3566-3573.

Hastuti S., Supriyono E., Mokoginta I., Subandiyono S., 2003 [Blood glucose response of gourami fish (*Osphronemus gouramy*, Lac.) to stress of environmental temperature changes]. Jurnal Akuakultur Indonesia 2(2):73-77. [in Indonesian]

Huo Z. M., Guan H. W., Rabbani M. G., Xiao Y. X., Zhang X. K., Fan C., Yan X. W., 2017 Effects of environmental factors on growth, survival, and metamorphosis of geoduck clam (*Panopea japonica* A. Adams, 1850) larvae. Aquaculture Reports 8: 31-38.

Huwoyon G. H., Kusmini I. I., 2010 [Growth performance of the albino and black tinfoil barb (*Barbonymus schwanenfeldii*) in pond]. Jurnal Iktiologi Indonesia 10(1):47-54. [in Indonesian]

Isaak D. J., Rieman B. E., 2013 Stream isotherm shifts from climate change and implications for distributions of ectothermic organisms. Global Change Biology 19(3):742-751.

Jasmine S., Begum M., 2016 Biological aspects of *Barbonymus gonionotus* (Bleeker, 1849) in the Padma River, Bangladesh. International Journal of Fisheries and Aquatic Studies 4(5):661-665.

Killen S. S., 2014 Growth trajectory influences temperature preference in fish through an effect on metabolic rate. Journal of Animal Ecology 83(6):1513-1522.

Lin F., Lin J., Liu X., Yuan Y., Liu G., Ye X., 2022 Effects of temperature on muscle growth and collagen deposition in zebrafish (*Danio rerio*). Aquaculture Reports 22: 100952.

López-Olmeda J., Sánchez-Vázquez F., 2011 Thermal biology of zebrafish (*Danio rerio*). Journal of Thermal Biology 36:91-104.

Mazumder S. K., Debi S., Das S. K., Salam M. A., Alam M. S., Rahman M. L., Al Mamun M. A., Khalil S. M. I., Pandit D., 2024 Effects of extreme-ambient temperatures in silver barb (*Barbonymus gonionotus*): metabolic, hemato-biochemical responses, enzymatic activity and gill histomorphology. Water 16(2):292.

Morales-Marín L. A., Rokaya P., Sanyal P. R., Sereda J., Lindenschmidt K. E., 2019 Changes in streamflow and water temperature affect fish habitat in the Athabasca River basin in the context of climate change. Journal of Ecological Modelling 407: 108718.

Nugroho E., Sukadi M. F., Huwoyon G. H., 2012 [Several types of local fish with potential for cultivation: domestication, hatchery technology, and health management of the cultivation environment]. Media Akuakultur 7(1):52-57. [in Indonesian]

Rachimi E. I., Raharjo, Halim D. A., 2014 [The effect of different stocking densities on the growth and survival of tengadak fish seed (*Barbonymus schwanenfeldii*)]. Jurnal Ruaya 4(2):57-62. [in Indonesian]

Ramee S. W., Lipscomb T. N., DiMaggio M. A., 2020 Evaluation of the effect of larval stocking density, salinity, and temperature on stress response and sex differentiation in the dwarf gourami and rosy barb. Aquaculture Reports 16:100287.

Ridwantara D., Buwono I. D. Handaka A. A., 2019 [Survival and growth test of common carp (*Cyprinus carpio*) fingerlings under different temperature ranges]. Jurnal Perikanan dan Kelautan 10(1):46-54. [in Indonesian]

Sánchez-Nuño S., Sanahuja I., Fernández-Alacid L., Ordóñez-Grande B., Carbonell T., Ibarz A., 2019 Oxidative attack during temperature fluctuation challenge compromises liver protein homeostasis of a temperate fish model. Comparative Biochemistry and Physiology Part B: Biochemistry and Molecular Biology 236: 110311.

Searle K., Hassan A. L. I., Clark T. D., Mock T. S., Turchini G. M., Francis D. S., 2024 Postprandial metabolism of Australian hybrid abalone (*Haliotis laevigata* x *H*. *rubra*) in relation to temperature and dietary protein manipulation. Aquaculture 579: 740185.

Solomon S., Qin D., Manning M., Chen Z., Marquis M., Averyt K. B., Tignor M., Miller H. L., 2007 Climate change: the physical science basis. Contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, UK, 996 pp.

Souchon Y., Tissot L., 2012 Synthesis of thermal tolerances of the common freshwater fish species in large western Europe rivers. Journal of Knowledge and Management of Aquatic Ecosystems 405:3.
Stone N., Shelton J. L., Haggard B. E., Thomforde H. K., 2013 Interpretation of water analysis reports for fish culture. Southern Regional Aquaculture Center 4606:1-12.
Subandiyono S., Hastuti S., 2016 Trivalent chromium (Cr^{+3}) in dietary carbohydrate and its effect on the growth of commonly cultivated fish. Jurnal Teknologi 78(4-2):233-237.
Subandiyono S., Hastuti S., Nugroho R. A., 2018 Feed utilization efficiency and growth of Java barb (*Puntius javanicus*) fed on dietary pineapple extract. AACL Bioflux 11(2): 309-318.
Sun J., Zhao L., Cui C., Du Z., He Z., Wang Y., Li X., Yang S., 2019 Influence of long-term temperature stress on respiration frequency, Na^+/K^+-ATPase activity, and lipid metabolism in common carp (*Cyprinus carpio*). Journal of Thermal Biology 83:165-171.
Syafei L. S., 2017 [Fish biodiversity and conservation in inland waters]. Jurnal Penyuluhan Kelautan dan Perikanan Indonesia 11(1):48-62. [in Indonesian]
Syed R., Masood Z., Hassan H. U., Khan W., Mustaq S., Ali A., Gul Y., et al, 2022 Growth performance, hematological assessment and chemical composition of Nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758) fed different levels of *Aloe vera* extract as feed additives in a closed aquaculture system. Saudi Journal of Biological Sciences 29(1):296-303.
Tian Y., Wang W., Jiang W., Zhang G., He J., Dong S., Zhou Y., Yang W., Tang Q., Yu Y., Gao Q., 2024 Non-targeted metabolomics provides insights into the distinct amino acid and lipid metabolism in liver tissues of rainbow trout (*Oncorhynchus mykiss*) cultured in seawater at different temperatures. Aquaculture 579:740188.
Thomas P., 1990 Molecular and biochemical responses of fish to stressors and their potential use in environmental monitoring. American Fisheries Society Symposium 8:9-28.
Trang N. T. D., Nonnerup D., Brix H., 2017 Effects of recirculation rates on water quality and *Oreochromis niloticus* growth in aquaponic systems. Aquacultural Engineering 78(B):95-104.
Walberg E., 2011 Effect of increased water temperature on warm water fish feeding behavior and habitat use. Journal of Undergraduate Research at Minnesota State University 11:13.
Watanabe T., Kiron V., 1994 Prospect in larval fish dietic (review). Aquaculture 124(1-4): 223-251.
Wedemeyer G. A., Meyer F. P., Smith L., 1999 Environmental stress and fish diseases. Narendra Publication House, Delhi, India, 192 pp.

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