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The Effect of Color and Photoperiod on Body Coloration and Growth of Juvenile Redclaw Crayfish (*Cherax quadricarinatus*)

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Abstract: This study aimed to determine the effects of light color and photoperiod on body coloration and growth performance of juvenile redclaw crayfish (Cherax quadricarinatus). A total of 144 juvenile crayfish were used in an experimental design consisting of six treatments based on two light colors (red and white LEDs) and three photoperiod regimes (6, 12, and 18 hours). The observed parameters included growth performance, survival rate, and changes in body coloration. The results showed that (1) red LED treatment with a 6-hour photoperiod produced the most optimal growth, whereas the 18-hour photoperiod treatment induced stress that led to reduced growth performance; (2) red LED treatments resulted in higher survival rates compared to white LED treatments; and (3) photoperiod significantly influenced changes in body coloration, with juveniles exhibiting blue and brown pigmentation. In conclusion, photoperiod affects affected the growth of juvenile crayfish, with red LED exposure for 6 hours representing representing the optimal condition. Differences in light color contribute to improved survival rates contributed to higher survival rates, while photoperiod plays a role in influencing body color changes played an important role in influencing changes in body coloration.
Keywords: Lobster; irradiation; growth

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INTRODUCTION

The species *Cherax quadricarinatus* has been identified as a fisheries commodity with significant economic value. The trajectory of increasing production has paralleled the escalation of market demand, implying an imperative for the large-scale implementation of *C. quadricarinatus* aquaculture. The transition in the utilization of *C. quadricarinatus* from an ornamental aquatic organism to a food commodity began to increase substantially during the period of 2002–2003 (Lesmana et al., 2022). Along with the rising economic value of this species, optimization of environmental factors within aquaculture systems has become a crucial aspect in supporting productivity and ensuring the sustainability of cultivation practices.

Freshwater lobster, also known as redclaw crayfish (*Cherax quadricarinatus*), is one of the crustacean species characterized by rapid growth performance, superior meat quality, and high economic value. According to FAO data (2021), total production reached approximately 260 tons across several countries, including Australia, Cambodia, Malaysia, and Indonesia. Environmental factors play a critical role in determining the reproductive performance, growth, and survival of *C. quadricarinatus* juveniles (Nie et al., 2024).

Changes in external lighting conditions trigger complex physiological and biochemical responses in animals through the crucial role of melatonin in mediating circadian rhythms. This endogenous mechanism in the brain regulates sleep–wake cycles and adaptation to environmental light conditions. Studies on *Penaeus vannamei* have shown that manipulation of light duration can enhance growth, feed efficiency, immune function, and antioxidant responses, thereby reducing mortality (Reddy et al., 2025; Wang et al., 2022). In addition to influencing growth and physiological rhythms, lighting also plays an important role in determining body color quality and pigmentation expression in economically valuable crustaceans.

Robust epidemiological studies and experimental evidence have consistently demonstrated a significant correlation between alterations in day–night patterns and various metabolic disorders. In aquatic organisms, the light–dark cycle represents a crucial biological factor that influences all stages of life, from embryonic development to sexual maturation. Circadian physiological and behavioral rhythms are regulated by a central biological clock located in the suprachiasmatic nucleus (SCN) of the hypothalamus. In addition to the SCN, various tissues throughout the body also possess the capacity to generate circadian biological rhythms (Arambam et al., 2020; Dannerfjord et al., 2021; Jiao et al., 2021).

Carotenoids constitute important compounds in crustaceans, playing roles in metabolic processes and behavioral adaptation to environmental conditions (Yeap, 2022). Astaxanthin is one of the primary pigments responsible for coloration changes in crustacean shells (Wade, 2005). These pigments are located in external tissues, particularly in the epidermal layer of the exoskeleton. Carotenoids may also function as carotenoproteins when bound to proteins. In addition to determining pigmentation, carotenoids can serve as indicators of stress conditions in crustaceans (Tume et al., 2009). Therefore, manipulation of light color and photoperiod may influence not only growth performance but also physiological stability and stress responses in juvenile lobsters.

The molting process (exoskeleton shedding) that occurs slowly or fails to occur can inhibit lobster growth and regeneration, particularly during the juvenile phase, which typically undergoes molting every 10 days. During molting, lobsters are highly vulnerable to cannibalism and disease attacks. Environmental conditions, such as the availability of shelters, represent an important strategy to reduce cannibalism rates (Fadhlan et al., 2021). Therefore, appropriate regulation of lighting conditions is an important factor in maintaining physiological balance during the juvenile growth phase.

Several studies have investigated the growth of *C. quadricarinatus* under artificial lighting conditions. First, research by Cheng (2023) concluded that red light with a photoperiod of 6L:18D (L = light on; D = light off) supported higher juvenile survival. Second, Nie (2024) reported that a photoperiod of 18L:6D under white light resulted in higher survival rates. Third, Titishania (2024) recommended white light with a 12L:12D photoperiod because it produced the lowest rate of morphological abnormalities (Cheng et al., 2023; Nie et al., 2024). The variation in findings among these studies indicates that there is still no consensus regarding the optimal combination of light color and photoperiod for the growth and survival of *Cherax quadricarinatus*. Differences in experimental methods, light intensity, and observed growth stages are likely factors contributing to these inconsistencies.

Although previous studies have examined the effects of light color or photoperiod separately, studies that simultaneously combine two light colors with three photoperiod regimes during the juvenile stage remain limited. This understanding is particularly relevant for freshwater lobster aquaculture, where appropriate lighting management has the potential to optimize growth, improve feed efficiency, and enhance resistance to stress and disease.

Therefore, this study aimed to determine the effects of light color and photoperiod on body coloration and growth in juvenile lobster (*Cherax quadricarinatus*).

Specifically, the study compared two light colors with three photoperiod regimes to identify the most optimal light color–photoperiod combination for freshwater lobster growth. This combinative approach has rarely been reported previously; therefore, further investigation is required to support the development of more effective and sustainable aquaculture practices.

METHOD

Experimental Animals and Experimental Design

A total of 144 juveniles of *Cherax quadricarinatus* were obtained from Fredi Kipenk Crayfish Hatchery. Prior to the experiment, the juveniles were acclimatized in aquaria for 1–2 days. Each set of three aquaria was equipped with either red or white LED lighting. The experiment consisted of six treatment groups, with 24 individuals per aquarium. The treatments were as follows:

1. Treatment 1: White light with a 6L:18D photoperiod (lights on at 00:00 and off at 06:00).
2. Treatment 2: White light with a 12L:12D photoperiod (lights on at 00:00 and off at 12:00).
3. Treatment 3: White light with an 18L:6D photoperiod (lights on at 00:00 and off at 18:00).
4. Treatment 4: Red light with a 6L:18D photoperiod (lights on at 00:00 and off at 06:00).
5. Treatment 5: Red light with a 12L:12D photoperiod (lights on at 00:00 and off at 12:00).
6. Treatment 6: Red light with an 18L:6D photoperiod (lights on at 00:00 and off at 18:00).

Each aquarium was covered with a red background layer. The rearing period lasted 30 days, and the lighting schedule was controlled using a timer lamp.

Materials

This study used juvenile freshwater crayfish (*Cherax quadricarinatus*) as the main experimental animals. A total of 144 juveniles measuring approximately 1 inch were obtained from Fredi Kipenk Crayfish Hatchery. The crayfish were fed commercial pellet feed containing 30% protein, and freshwater was used as the culture medium.

Equipment

The equipment used in this study included: Aquaria (60 cm × 40 cm × 20 cm), LED lights (red and white), Timer lamp (Nutron), Red background stickers, pH meter (Hanna), Thermometer, TDS meter (TDS-3), Refractometer (ATC), Lux meter (Victor 1010D), Digital balance (CX-series), Measuring tape, Millimeter block, Fish net

Rearing Procedure

Before the treatments began, the initial body weight of each crayfish was recorded. During the 30-day rearing period, the crayfish were fed commercial pellet feed twice daily, at 08:00 and 16:00 (WIB). To maintain optimal environmental conditions, tank cleaning and partial water replacement were carried out every three days.

Water Quality Monitoring

Water quality was closely monitored every three days throughout the experiment to ensure optimal environmental conditions. The parameters measured included: Temperature, pH, Dissolved oxygen (DO), Total Dissolved Solids (TDS), Salinity, Nitrate–ammonia concentration, Light intensity

Observation Parameters

The observed parameters included: Absolute weight growth, Absolute length growth, Survival rate, Specific growth rate, Weight growth rate, Length growth rate. Each parameter was calculated using the following formulas.

1. ***Absolute Weight Growth (BM)***

Absolute weight growth was calculated using the formula proposed by Sari et al. (2025):

$$BM = w_t - w_0 \quad \textbf{(1)}$$

Where:
BM = weight gain (g)
Wt = final weight (g)
Wo = initial weight (g)

2. ***Absolute Length Growth (PM)***

Absolute length growth was determined using the formula from Lesmana et al. (2022):

$$PM = p_t - p_0 \quad \textbf{(2)}$$

Where:
PM = absolute length growth (cm)
Pt = final length (cm)
Po = initial length (cm)

3. ***Survival Rate (SR)***

Survival rate was calculated using the formula from Nie et al. (2024):

$$SR\ (\%) = \frac{N_t}{N_0} \times 100\% \quad \textbf{(3)}$$

Where:
SR = survival rate (%)
Nt = number of crayfish at the end of the experiment
No = number of crayfish at the beginning of the experiment

4. ***Specific Growth Rate (SGR)***

Specific growth rate was calculated using the formula from Sari et al. (2025):

$$LPS = \frac{ln(w_t) - ln(w_0)}{t} \times 100\% \quad \textbf{(4)}$$

Where:
SGR = specific growth rate (%)
ln(Wt) = natural logarithm of final weight (g)
ln(Wo) = natural logarithm of initial weight (g)
t = experimental duration (days)

5. ***Weight Growth Rate (LPB)***

Weight growth rate was calculated using the formula from Nie et al. (2024):

$$LPB = \frac{w_f - Wi}{Wi} \times 100\% \quad \textbf{(5)}$$

Where:
LPB = weight growth rate (%)
Wf = final weight
Wi = initial weight

6. Length Growth Rate (LPP)

Length growth rate was measured using the formula from Nie et al. (2024):

$$LPP = \frac{L_f - L_i}{L_i} \times 100\% \qquad (6)$$

Where:
LPP = length growth rate (%)
Lf = final body length (cm)
Li = initial body length (cm)

Body Color Observation

Body color observations were conducted after 30 days of the experiment. Changes in coloration were assessed to determine whether the treatments resulted in color variations such as blue, yellow, or red.

Data Analysis

The collected data were analyzed using analysis of variance (ANOVA) to determine the effect of the treatments. If significant or highly significant differences were detected, a Duncan's multiple range test was performed as a post hoc test to identify the best treatment response.

RESULTS AND DISCUSSION

The results of this study are presented in the form of tables and figures to illustrate the effects of the combination of light color and photoperiod on growth, survival rate, and body color changes of juvenile *Cherax quadricarinatus*.

Table 1. Final observation results of juvenile *C. quadricarinatus* growth

Aquarium	AW (g)	AL (cm)	SGR (%)	WGR (%)	LGR (%)
Treatment 1	1,20 $\pm$ 0,66^b	1,81 $\pm$ 0,67^b	3,45 $\pm$ 1,22^b	199,17 $\pm$ 109,8^b	71,33 $\pm$ 27,43^b
Treatment 2	1,14 $\pm$ 0,25^b	1,66 $\pm$ 0,25^b	3,52 $\pm$ 0,5^b	190,00 $\pm$ 42,13^b	65,43 $\pm$ 10^b
Treatment 3	0,42 $\pm$ 0,45^a	0,70 $\pm$ 0,73^a	1,43 $\pm$ 1,53^a	68,50 $\pm$ 74,53^a	27,44 $\pm$ 28,93^a
Treatment 4	0,80 $\pm$ 0,34^b	1,67 $\pm$ 0,35^b	2,74 $\pm$ 0,82^b	133,67 $\pm$ 57,02^b	65,59 $\pm$ 13,8^b
Treatment 5	1,04 $\pm$ 0,16^b	1,68 $\pm$ 0,18^b	3,34 $\pm$ 0,32^b	173,83 $\pm$ 26,31^b	66,26 $\pm$ 7,13^b
Treatment 6	1,11 $\pm$ 0,47^b	1,71 $\pm$ 0,43^b	3,36 $\pm$ 0,96^b	184,50 $\pm$ 77,87^b	67,28 $\pm$ 16,97^b
P = *Value*	0,001	0,000	0,000	0,001	0,000

Note: AW = Absolute Weight; AL = Absolute Length; SGR = Specific Growth Rate; WGR = Weight Growth Rate; LGR = Length Growth Rate. Treatment 1 = White LED 6L:18D; Treatment 2 = White LED 12L:12D; Treatment 3 = White LED 18L:6D; Treatment 4 = Red LED 6L:18D; Treatment 5 = Red LED 12L:12D; Treatment 6 = Red LED 18L:6D. Different superscript letters (^{a,b}) indicate significant differences at $P < 0.05$.

Table 1 shows the results of data analysis using a one-way ANOVA, which indicated significant differences among treatment groups in the growth performance of *Cherax quadricarinatus*. For the parameters of absolute weight, absolute length, specific growth rate, weight growth rate, and length growth rate, the Duncan post hoc test revealed significant differences between Treatment 3 and Treatments 1, 2, 4, 5, 6. However, no significant differences were found among Treatments 1, 2, 4, 5, and 6.

The mean values for the absolute weight (AW) parameter showed that the highest value occurred in Treatment 1 (1.20 g), while the lowest value occurred in Treatment 3 (0.42 g). For the absolute length (AL) parameter, Treatment 1 showed the highest value of 1.81 cm, whereas Treatment 3 had the lowest value of 0.70 cm. In terms of weight growth rate (WGR), Treatment 1 produced the highest value of 199.17%, and the length growth rate (LGR) also reached its highest value in Treatment 1 at 71.33%.

These results indicate that Treatment 1 (white LED illumination with a photoperiod of 6 hours light and 18 hours dark) was the most optimal treatment for the growth of juvenile *Cherax quadricarinatus*. This finding is consistent with the study of Wang (2024), which reported that under a 12L:12D light–dark cycle, lobsters exhibited optimal growth performance. This occurs because a photoperiod consisting of equal light and dark phases mimics natural daily cycles that significantly influence growth rate, survival rate, and lipid metabolism in juvenile lobsters.

Similarly, Nie (2024) reported that shorter light exposure periods produced higher body weight compared to longer illumination periods. Lower light exposure combined with longer dark periods allows lobsters to obtain more energy due to increased feeding activity (Jamaluddina, 2024). Low-intensity illumination combined with a complete light spectrum can support better growth of juvenile lobsters because it fulfills physiological requirements for growth without causing environmental stress.

Photoperiod is one of the environmental factors that can improve survival conditions, growth, and feeding activity in juvenile lobsters (Nasution, 2024). Wang (2022) demonstrated that shorter illumination periods improve growth performance and reduce mortality rates. Excessive light exposure may cause juvenile lobsters to prioritize survival behavior rather than growth due to environmental stress induced by prolonged illumination.

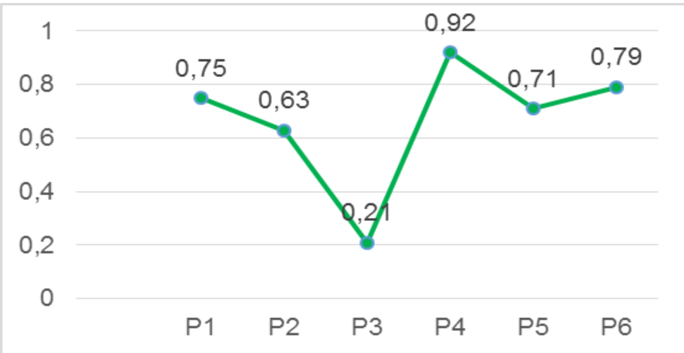

Figure 1. Survival Rate (SR): Treatment 1 (P1) = White 6L:18D; Treatment 2 (P2) = White 12L:12D; Treatment 3 (P3) = White 18L:6D; Treatment 4 (P4) = Red 6L:18D; Treatment 5 (P5) = Red 12L:12D; Treatment 6 (P6) = Red 18L:6D.

The survival rate of juvenile *Cherax quadricarinatus* (Figure 1) showed that Treatments 1, 2, 4, 5, and 6 resulted in higher survival compared to Treatment 3, which is consistent with the observed growth results (Table 1). In general, crustaceans are highly susceptible to cannibalism, particularly during the pre-molt or molting phase (Zheng, 2023). One of the factors influencing cannibalism levels is the availability of shelters within the culture environment (Mamuaya, 2019).

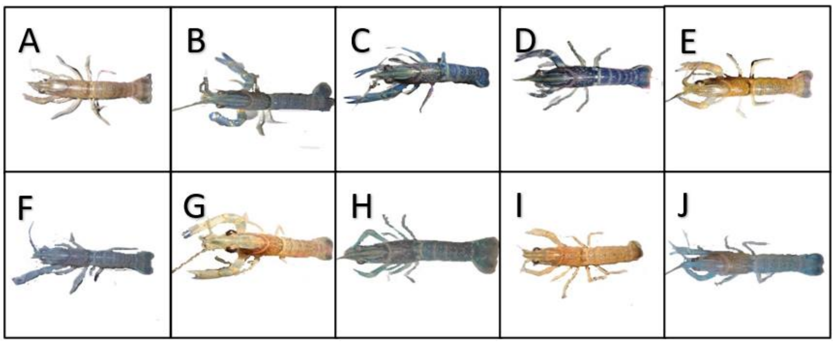

Figure 2. Changes in lobster body coloration: A = Treatment 1 (brown); B = Treatment 1 (blue); C = Treatment 2 (blue); D = Treatment 3 (blue); E = Treatment 4 (blue); F = Treatment 4 (brown); G = Treatment 5 (blue); H = Treatment 5 (brown); I = Treatment 6 (blue); J = Treatment 6 (brown).

The duration of illumination had a more significant influence because it is directly associated with the circadian rhythm and endocrine system of lobsters. An appropriate photoperiod regulates hormone release from the X-organ–sinus gland complex located in the eyestalk. These hormones regulate the Molt-Inhibiting Hormone (MIH), which directly determines molting frequency. If light duration is not regulated consistently, lobsters may experience chronic stress, which disrupts the molting cycle regardless of the light color used.

This observation is consistent with the findings of Cheng (2023), who reported that shorter illumination periods support the survival of juvenile lobsters. Although differences in light color did not have a major effect, they still influenced growth due to variations in the spectral characteristics of each light color. Wijianto (2021) reported that exposure to LED light spectra can improve growth performance. Similarly, Wu (2020) found that light spectrum affects growth and stress responses, where shorter wavelengths have a positive effect on juvenile growth, while longer wavelengths have negative effects. Ma (2023) also reported that constant lighting with a rhythm similar to natural aquatic environments improves stress resistance and metabolic performance.

Photoperiod also influences antioxidant activity in juvenile *Cherax quadricarinatus*. Free radicals can cause protein carbonylation, DNA damage, and lipid peroxidation, which are sensitive biomarkers of physiological responses (Wei & Yang, 2015). Increased reactive oxygen species (ROS) in crustaceans varies with photoperiod changes and may induce oxidative stress, thereby triggering immune responses in organisms (Wang, 2023). According to Nie (2024), malondialdehyde (MDA) levels increase with higher illumination intensity. MDA is an indicator of oxidative damage to lipids, amino acids, and DNA. Elevated MDA levels may lead to mutagenesis, and excessive concentrations can ultimately cause mortality (Long, 2006). These findings correspond with the growth observations presented in Table 1.

Observations of body color changes in juvenile *Cherax quadricarinatus* (Figure 2) showed that in Treatment 1, 14 individuals changed color to blue and 4 individuals became brown. In Treatment 2, 15 individuals turned blue. In Treatment 3, 5 individuals turned blue. In Treatment 4, 10 individuals turned blue and 12 turned brown. In Treatment 5, 12 individuals turned blue and 5 turned brown. In Treatment 6, 6 individuals turned blue and 13 turned brown. These findings are consistent with the study of Wei (2020), which reported that body color changes in *Cherax quadricarinatus* depend on environmental lighting conditions. Exposure to brighter environments tends to produce yellowish-brown coloration, whereas darker environments tend to produce darker blue coloration.

The measured water quality parameters included temperature, pH, Total Dissolved Solids (TDS), Dissolved Oxygen (DO), nitrate ammonia, and nitrite ammonia. The average values were 26.1°C for temperature, pH 7.9, TDS 110.1 ppm, DO 0.7 mg/L, nitrate ammonia 1.16 mg/L, and nitrite ammonia 0.03 mg/L. Based on Government Regulation No. 22 of 2021, the values of temperature, pH, and TDS were within acceptable ranges for aquaculture and were considered suitable for cultivation. However, the DO value was relatively low according to the same regulation, indicating that the water quality during the culture period may have experienced environmental contamination. Meanwhile, nitrate ammonia and nitrite ammonia values were relatively low and still within acceptable limits according to Government Regulation No. 22 of 2021. Therefore, the potential contamination was unlikely to originate from ammonia compounds, and further analysis is required to determine the specific source responsible for the low DO levels.

CONCLUSION

Based on the results of this study, it can be concluded that photoperiod *had a significant effect on* significantly affected the growth of juvenile lobsters. The treatment with a *6-hour photoperiod under red background lighting produced the most optimal results* 6-hour photoperiod under red background lighting produced the optimal growth performance. Differences in light color *were also able to increase the survival rate* also increased the survival rate, as observed in the treatment using red LED lighting. In addition, photoperiod *influenced changes in body coloration* affected body coloration, *resulting in body color variations such as* resulting in color variations including blue and brown.

RECOMMENDATION

Future studies may apply shorter lighting durations to further evaluate the effect of photoperiod on lobster growth and survival. It is also recommended to design larger shelters in order to reduce the high mortality rate.

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