GROWTH AND SURVIVAL IN FOUR COLOR VARIANTS OF *Procambarus clarckii* FRY REARED IN A RECIRCULATING SYSTEM

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Abstract. *Procambarus clarckii* is a freshwater lobster with several body colors and is one of the commodities in demand by ornamental lobster hobbyists. Like the Crustacea subphylum, its growth begins with periodic skin changes. Its survival plays a role in lobster cultivation. The research aimed to examine the growth and survival of *P. clarckii* in blue, orange, brown, and white colors. It was maintained for two months with a recirculation system and fed commercial pellets. The research was designed in a Completely Randomized Factorial with eight treatment combinations and three replications. The treatments were in different initial lengths, between 2.0-2.5 cm (A) and 3.0-3.5 cm (B). The parameters observed were the frequency of molting and survival rate. The study results showed that during two months of observation, *P. clarckii* with four different body colors experienced skin changes 6-7 times in treatment A and 5-6 times in treatment B. The highest survival rate occurred in orange lobster, followed by brown, blue, and white lobsters in treatments A and B with water quality conditions that were suitable for the required water quality standards such as temperature, TDS, pH, and DO, both in lobster and filtration-recirculation containers.

Keywords: *Procambarus clarckii*, filtration-recirculation, molting, survival, commercial feed

A. Introduction

The red swamp crayfish, *Procambarus clarkii* (Girard, 1852), is an autochthonous species from the Northeast of Mexico South and Central United State (Hobbs et al., 1989), which was introduced worldwide and has become the dominant freshwater crayfish in almost all areas it occupies (Henttonen and Huner, 1999). Morphological characteristics of crayfish, such as color and body length, were influenced by its habitat. Marbled crayfish (*Procambarus virginalis*) have creamy, black and white spots on the branchiostegal and abdominal parts of the carapace (Vogt et al., 2018).

Coloration in marbled crayfish is also highly variable. The specimens captured from Lake Moosweiher showed a dark brown to olive dorsally and reddish brown laterally. Meanwhile, the laboratory-raised samples showed variable colors like brown, ochre, reddish, and bluish (Vogt et al., 2018). In a word, the wild specimens have a darker color than the cultured ones (Pan et al., 2020). However, Kent (1901) reported that the color of crayfish found in the shallow water in the small streams was not always similar to the color of the environment. The red color surface was caused by exposure to sunlight, and the non-red color crayfish samples turned red when exposed to sunlight (Kent, 1901). Notably, no matter what kind of colors the crustacean shell showed naturally, they eventually turned to a similar bright red-orange when cooked. The degree of red color development not only reflects the freshness of crustaceans but also plays a significant role in the consumer acceptability of crustacean commodities (Brookmire et al., 2013; Elizabeth et al., 2009; Pan et al., 2018).

Crayfish (Decapoda) are essential to invertebrate groups in global aquaculture. The American-originated Procambarus (swamp crayfish) genus is an acceptable culture animal as in yield than the genera with natural distribution areas in Europe, the Middle East, Asia, the Far East, and Australia (Kaya et al., 2021). Most crayfish cannot tolerate polluted water, although some species, like *P. clarkii*, are more resilient and help maintain the health of aquatic ecosystems by controlling algal growth and consuming organic matter (Needon et al., 1971; Crandall and Buhay, 2008).

This species *P. clarkii* is the most commercial species in the world and can grow rapidly, reaches a length up to 15 cm in length when mature (Henttonen and Huner, 1999; Loureiro et al., 2015). However, some reach a size of 57 to 110 mm when mature. The largest specimen reported, from Kenya, measured 160 mm (Huner and Barr, 1991). This lobster has become a highly sought-after species over the last decade. Red swamp crayfish farming has recently been considered a promising sector (Tian et al., 2020). As a popular food product, crayfish have high-quality protein, are low in fat, and are rich in minerals (Amine et al., 2008).

According to Huner and Avault (1976), adult *P. clarckii* molts once a year, but young ones molt more often, up to five times monthly. So far, the information that has been published is generally about the occurrence of molting in the life of *P. clarckii* in nature or laboratory maintenance while in household-scale cultivation. It is still minimal. This study obtained data and information on molting frequency in orange, brown, blue, and white *P. clarckii* seeds maintained in apartment-style containers with a recirculation system, and fed commercially manufactured feed.

B. Methods

The study was conducted in a field laboratory from May to July 2024. Implementing an experimental method with a Completely Randomized Factorial design with eight treatment combinations and three replications, 24 try units, and each try unit contains ten lobsters. The treatment consists of lobster body colors (orange, brown, blue, and white) with different initial lengths: A = 2.0-2.5 cm and B = 3.0-3.5 cm. A combination of treatments was A-Orange, A-Brown, A-Blue, A-White, B-Orange, B-Brown, B-Blue, and B-White. The tools used in the freshwater lobster maintenance technique *P. clarkii* with a recirculation system are a circulation pump, a bucket for filtration media, a plastic tub, small split stones, a sieve, a PVC pipe, a PVC pipe cover, a wire mesh, a bio ball, a foam sponge, a wooden support pole, an analytical scale, a caliper, a hatching place, a cellphone camera, a thermometer, a water quality multitester and stationery. The dimensions of the maintenance container are: the length of the upper part is 56 cm and 53 cm (bottom); the width of the upper part is 42 cm and 40 cm (bottom). The cultivation container applies an apartment system equipped with a filtration bucket and a recirculation machine. The *P. clarkii* samples were observed from breeders in Purwokerto Utara District, Banyumas Regency. Illustrations of the filtration reactor and cultivation container are shown in Figure 1.

Evaluation of Survival rate (SR) and molting frequency were calculated for each container as follows:

SR (%) = 100 * (Nf/Ni)

Where:

Nf = final number of crayfish,
Ni = initial number of crayfish,
Wf = final crayfish

The molting frequency was calculated by summing all molested lobsters during maintenance and dividing by all lobsters used for research samples. All results were statistically analyzed (Anova) using the computer program SPSS for significant differences. Water quality measurements were performed using a water quality multitester.

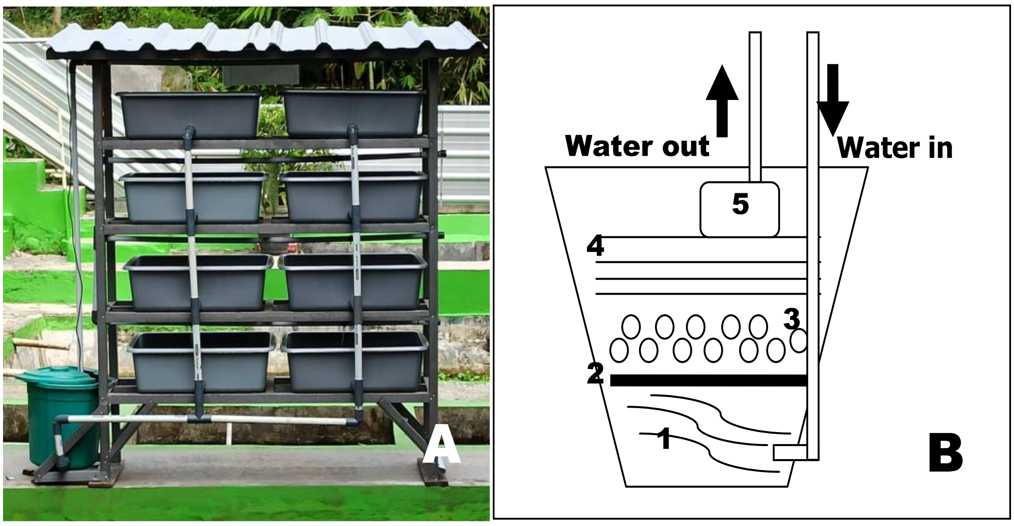

Figure 1. Circulation system applied to *Procambarus clarkii* culture

Where:
Container A was taken for cultivation of *P. clarkii*
Container B was taken for filtration-recirculation
1.coconut fiber; 2.woven wire; 3.bioball ; 4.foam sponge ; 5. recirculation machine

C. Results And Discussion

1. Result

In this experiment, 240 individuals with four variant colors (Figure 2.) were maintained at two levels of total length. All of the samples were fed commercial feed at libitum. The proximate analysis of the commercial feed showed that each 100 mg consisted of 71.80% dry matter, 28.20% water, and 8.75% ash. The dry matter contained 19.88% crude protein, 3.41% crude fat, 12.38% crude fiber, 8.75% ash, and 55.58% BETN.

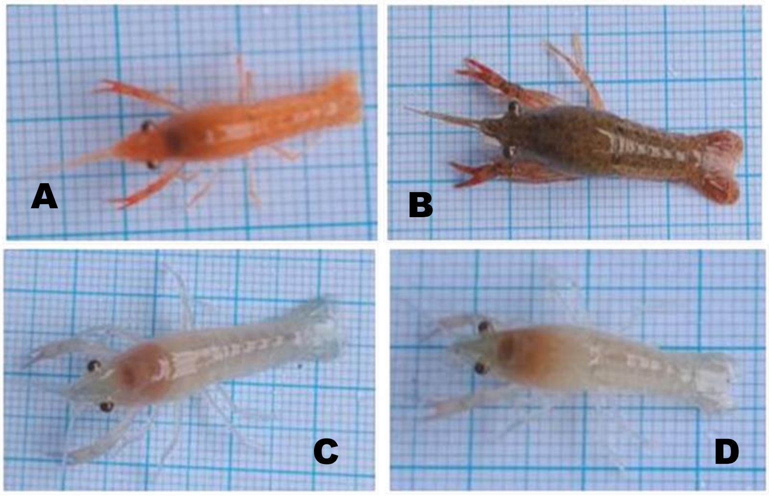

Figure 2. Morphology of *P.clarckii* fry

A. orange; B. Brown; C. Blue and D. White

The results of monitoring survival rate (SR) and molting frequency in orange, brown, blue, and lobster seeds with different initial sizes and fed commercial feed ad libitum are shown in Table 1. The condition of lobsters during molting and failed molting is shown in Figure 3.

Table 1. Survival rate and molting frequency

Experiment	SR (%)	Molting Frequency
A-Orange	80-90 (86.67±5.77)^{bcdefgh}	6-7 (6.5±0.53) ^{efgh}
A-Brown	80-90 (83.33±5.77) ^{acdefgh}	6-7 (6.4±0.52) ^{efgh}
A-Blue	40-50 (46.67±5.77) ^{abdefgh}	6-7 (6.3±0.48) ^{efgh}
A-White	20-30 (23.33±5.77) ^{abcefgh}	6-7 (6.4±0.52) ^{efgh}
B-Orange	90-100 (93.33±5.77) ^{abcdgh}	5-6 (5.6±0.52) ^{abcd}
B-Brown	90-100 (93.33±5.77) ^{abcdegh}	5-6 (5.3±0.48) ^{abcd}
B-Blue	60-70 (63.33±5.77) ^{abcdefh}	5-6 (5.3±0.48) ^{abcd}
B-White	40-50 (43.33±5.77) ^{abcdefg}	5-6 (5.4±0.52) ^{abcd}

*Mean values with different superscripts differ significantly ($P < 0.05$)

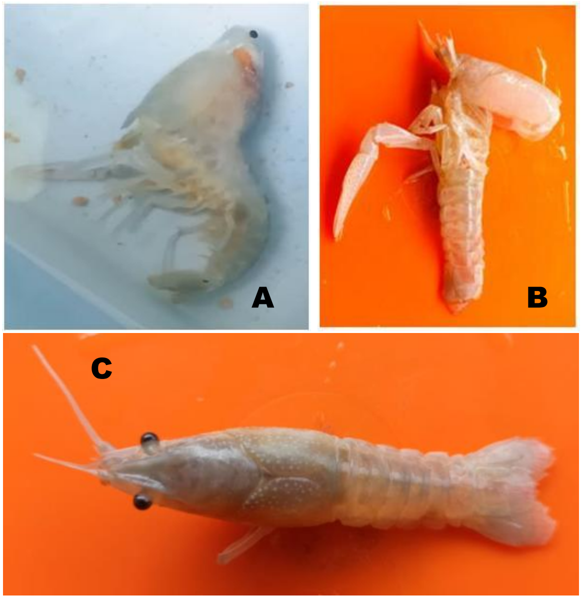

Figure 3. Molting of *P.clarckii*

A. Molting process; B-C. molting failure

Water quality measurements were carried out on lobster containers and filtration-recirculation; the results are presented in Table 2.

Table 2. Water quality in lobster containers and filtration-recirculation

Parameter	Sample	Value
Temperature (°C)	Lobster container	28.2-28.8 (28.63±0.29)
	Filtration-recirculation	28.2-28.8 (28.63±0.29)
pH	Lobster container	7.06-7.27 (7.21±0.10)
	Filtration-recirculation	7.15-7.20 (7.17±0.02)
TDS (ppm)	Lobster container	179-181.4 (181.07±0.82)
	Filtration-recirculation	181 (181±0.2)
DO (ppm)	Lobster container	8.4-8.49 (8.44±0.04)
	Filtration-recirculation	8.3-8.41 (8.35±0.06)

2. Discussion

Identification of *P. clarkii* is easy. Like other members of the family Cambaridae, it possesses a strong spur on the inner side of the carpopodite. Moreover, the propodite has strong spines on its inner side and conspicuous knots on its dorsal face. The branch cardiac grooves of the carapace converge dorsally. Lateral spines or tubercles in front of and behind the cervical groove are absent or reduced. The rostrum lacks a median keel and has an apparent triangular shape, the sides tapering anteriorly. The head itself is elongated and narrowing towards the front. Special attention is needed to identify juvenile crayfish, which are not colored red and look very similar to other Procambarus species, i.e., marbled crayfish (Boets et al., 2009).

Referring to the characteristics described by Boets (2009), the *P. clarckii* observed is one species but has intraspecies variations in the form of differences in the color of its exoskeleton. According to Gherardi (2011), the carapace color is dark red, orange, or reddish brown, although blue, yellow, white, and black varieties known as chelae are typically red on both surfaces. Wade (2010) and Kaldre et al. (2015) argue that color differentiation in crayfish depends on several factors, including morphological characteristics, genetics, environmental conditions, and diet.

Analysis results the survival rate (SR) showed that the highest survival rate occurred in orange lobsters, followed by brown, blue, and white lobsters in treatments A and B. White lobsters experienced the highest mortality rate. White lobsters may have higher immunity than other colors. During the study, lobster deaths were generally caused by failed molting or successful molting. However, when the body was still soft, it was eaten by its friends because this group of Crustacea has a cannibalistic character. Survival is vital in crayfish cultivation because of the cannibalism problem (Taugbøl and Skurdal, 1992). Cannibalism is defined as an animal eating another of their kind, which includes the consumption of already dead animals as well as agonistic behavior of conspecifics attacking/eating the other, leading to injury or death (Polis, 1981). Cannibalistic behaviors are found in many decapod crustacean groups and can substantially alter population dynamics in the wild (Polis, 1981; Claessen et al., 2003). Crayfish are generally less cannibalistic than crabs or lobsters. Nevertheless, this is still a significant limitation for their aquaculture, particularly for the *A. astacus* and *P. leniusculus* industry (Gonzalez et al., 2010; Ghanawi and Saoud, 2012; Franke et al., 2013).

Molting is a common phenomenon in all crustaceans and is essential for growth, metamorphosis, and reproduction. The molting cycle consists of the molting phase, postmolt phase, intermolt phase, and the final phase, the premolt phase. Molting is a complex and cyclical process, culminating in ecdysis or release exoskeleton (Chang and Mykles, 2011). The molting cycle consists of molt, postmolt, intermolt, and premolt (Kuballa and Elizur, 2007). In crustaceans, molting is a part of growth and development (Ghanawi and Saoud, 2012) and is an energy-intensive process (Raviv et al., 2008). Molting is very important in lobster growth because lobsters can grow through molting. Several factors that influence the growth and survival of freshwater lobsters are fry quality, type of fry, water quality, disease, and molting success in changing new skin (Ahvenharju, 2007).

Crustaceans grow and develop naturally by periodically molting their exoskeleton (Genodepa et al., 2004; Hamasaki et al., 2002; Holme et al., 2007). Like other crustaceans, their growth is influenced by many factors, such as water temperature, light intensity, quantity and quality of nutrients, and population density (Aiken, 1980; Reynolds, 2002). The molting in crustaceans is triggered by ecdysteroids, which are secreted from a pair of Y organs (Skinner, 1985; Spindler et al., 1980).

The water quality conditions measured in this research still meet the required quality standards, namely temperature, TDS, pH, and DO, both in lobster containers and filtration recirculation. Based on the opinion of Huner (1990) and Mazlum and Eversole (2005), water temperatures and dissolved oxygen (DO) during the experiment were within acceptable ranges for cambarid crayfish growth.

Crayfish are considered good animals for culturing because they exhibit fast growth rates at temperatures between 23-31°C, require a relatively simple spawning technique, and tolerate a wide range of water qualities (Ibrahim and Khalil, 2009; Ibrahim, 2024). Temperature is an essential environmental parameter influencing Crayfish growth, feeding, and activity (Hmer and Barr, 1991).

The reason for the differences in survival values and molting frequencies in this study is thought to be related to species behavior. Survival rates in cultured animals have complex mechanisms influenced by many variables. Previous studies have revealed that crayfish growth, survival, and cannibalism are influenced by various factors, such as water parameters (temperature and dissolved oxygen), photoperiod, diet, shelter, density, competition, and species and size differentiation (Mazlum and Eversole, 2005; Farhdi et al., 2014)

D. Conclusion

The results of the study showed that during two months of treatment, *P. clarckii* with four different body colors experienced the following:

1. Skin shedding 6-7 times in treatment A and 5-6 times in treatment B.
2. The highest survival rate occurred in orange lobsters and the lowest in white lobsters, both in treatments A and B.

E. Acknowledgment

The author would like to thank the Rector and LPPM of Jenderal Soedirman University for the financial support to complete this research, which is part of the Professor Research, funded by BLU for the 2024 Fiscal Year, through Work Contract Number 26.741/ UN23.35.5/PT.01/II/2024.

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