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Short Communication

Do Light Factors Affect Crustacean Larvae Growth?

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ABSTRACT

Light is a key environmental factor that affects every life stage of crustaceans, especially during the larval stage. In early development, after hatching from the egg, crustaceans exist as larvae that float in the water column and are particularly susceptible to light exposure. This short review aims to compile existing findings regarding the effects of light on crustacean larvae. Overall, current findings suggest that a long photoperiod (more than 18 hours of light), higher light intensity, and white light may be particularly beneficial for the survival and growth of crustacean larvae. The collected information may be useful in optimizing rearing protocols in hatchery settings. However, further studies are needed to gain a more comprehensive understanding of how lisght affects crustacean larvae as a whole.

Keywords: Light, crustacean larvae

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INTRODUCTION

Light is a crucial environmental factor that influences every life stage of crustaceans, primarily during the larval stage. Light influences the aquatic environment of crustaceans in terms of spectrum, photoperiod, and intensity (Boëuf and Bail, 1999), which all these factors are affected by season, time of day, depth, water quality, and weather (Bermudes and Ritar, 2008). Light spectrum is filtered by the depth of

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water column of the oceans or lakes, where shorter wavelengths (<390 nm, e.g., violet) and longer wavelengths (>~450 nm, e.g., red and orange) are absorbed by water, leaving the oceans and lakes appear to be blue (Villamizar et al., 2011). Photoperiod refers to the light duration to which crustaceans are exposed within a 24-hour period that regulates biological rhythms, primarily hormonal activity (Nie et al., 2024). Fourteen hours of light and above are considered long, whereas light hours reduced below 12 hours are considered short. Light intensity refers to light brightness, often influenced by the position of the sun. For example, at the ocean surface, light intensity is reduced (0.1-100 lux) during dawn and dusk, and reaches up to 100,000 lux during the daytime (Fourooghifard et al., 2020).

Crustacean is derived from Latin words, referring to chitinous exoskeleton and aquatic crustaceans are categorised into four main groups, including crabs, lobsters, prawns and shrimps (Covich and Thorp, 2001). Life stages of these aquatic crustaceans begin in the form of larvae that float in the water column, which then settle as benthic juveniles. In crabs, the larval stages comprise of Zoea 1 up to Zoea 5 before entering the Megalopa stage. The larval stages could be differentiated based on the setae, maxillipeds (modified appendages) and antennules (sensory antennae) (Li et al., 2022), while the Megalopa stage is a stage resembling juvenile crabs with a flattened body, long eyestalk and the presence of claws (Li et al., 2022). In shrimp (e.g., whiteleg shrimp, *Litopenaeus vannamei,* tiger shrimp, *Penaeus monodon*, and banana shrimp, *Penaeus merguiensis*), larval developments consist of six nauplius stages, three zoea stages, three mysis stages, and postlarval stages before entering the juvenile stage (Wei et al., 2014). In lobster (e.g, spiny lobster, *Panulirus* sp.), the larval stage is known as phyllosoma (referring to leaf-shaped body), which floats in the water column for a longer period than other types of aquatic crustacean, with more than 5 months up to 2 years (Briones-Fourzán et al., 2021). In general, all these types of larvae, such as Zoea, mysis, and phyllosoma, had a higher tendency to show positive phototactic behaviour during larval stages, indicating the importance of light for their development, with the eye as the main light-sensing organ that is involved in this role (Boëuf and Bail, 1999; Porter, 2001).

Light factors are paramount for the development of crustacean larvae, and previous evidence suggests that light influences photoreceptors, foraging behaviour, and feeding. However, these effects are still scarce and need to be further reviewed. Hence, the objective of this paper is to review the existing findings related to light and crustacean larvae, focusing on survival, growth, metamorphosis, feeding and the potential mechanism of light response. The information compiled may be beneficial to optimise rearing protocols in aquaculture, overcoming the main issues regarding the reduction of feed supply nowadays. This review compiles information from articles published in scientific journals. We used Web of Science (WOS), Scopus, Google Scholar (GS), and Google as search engines to identify relevant references. The following keywords were used in our searches: "(light) AND (crab OR lobster OR shrimp OR prawn OR crustacean)." A total of 26 articles were included in this paper, reflecting the limited number of studies available in this field.

Effect of Light on Crustacean Larvae: Photoperiod, Light Intensity and Spectrum

Previous studies have suggested that crustacean larvae grown under long photoperiods (>18 hours of light) exhibit the best survival rates. For instance, larvae of crustaceans such as the blue swimming crab, *Portunus pelagicus*, giant freshwater prawn, *Macrobrachium rosenbergii*, green rock lobster, *Sagmarius verreauxi*, kuruma prawn, *Penaeus japonicus*, red rock lobster, *Jasus edwardsii*, and white-leg shrimp, *L. vannamei* showed the highest survival under these conditions (Figure 1). In crabs, Andrés et al. (2010) found that larvae of the blue swimming crab were able to survive to the megalopa stage under constant darkness (0 hours of light). However, survival was significantly reduced to less than 20%, suggesting that larvae heavily rely on light for feeding. Another study by Ravi and Manisseri (2008) indicated that the Zoea 3 and Zoea 4 stages of blue swimming crab larvae were influenced by light exposure, with longer photoperiods (18 hours of light) often resulting in higher survival rates of up to 85% (Ravi & Manisseri, 2011). Similarly, Ikhwanuddin et al. (2019) observed that blue swimming crab larvae depend on light for more efficient feeding, particularly newly hatched zoea, which were observed feeding more frequently (three to four times) during the daytime compared to nighttime. Bermudes and Ritar (2008) stated that the phyllosoma of the red rock lobster had a significantly higher feeding rate under longer photoperiod (24 hours), which fed up to 20 *Artemia* per individual per day. Similarly, Fitzgibbon and Battaglene (2012) showed phyllosoma of green rock lobster (instar 1- 5) and late-stage phyllosoma (instar 15 - 17) fed higher rate of artemia under 24 hours of light at feeding rates of 0.012 mg and 110 mg *Artemia* per individual per hour, respectively. Sanudin et al. (2014) also demonstrated that larvae of white-leg shrimp had a higher ingestion rate under light conditions (62%) than shorter photoperiod (39.3%), suggesting that shrimp larvae highly depend on their eye for feeding. In contrast, Ikhwanuddin et al. (2019) and Andrés et al. (2010) exhibited continuous darkness caused a decrease in survival of blue swimming crab larvae, with less than 30% and 50% survival, respectively. Likewise, the phyllosoma of red rock lobster had a reduced feeding rate in continuous darkness (Bermudes and Ritar, 2008). Overall, a prolonged photoperiod, longer than 18 hours, improves survival, growth, and feeding rate, whereas continuous darkness had negative effect on survival and feeding rate.

Since most crustacean larvae are visual feeders, their feeding activity increases with light intensity. Higher light intensity enhances visual function, allowing larvae to better recognise and capture prey, up to an optimal brightness level (Lee et al., 2017). Most crustacean larvae species had improved feeding, growth, and survival under higher light intensities (greater than 1000 lux). A study by Ikhwanuddin et al. (2019) found that the growth of blue swimming crab larvae at stages Zoea 1, Zoea 2, and Zoea 3 correlated with light intensity. A light intensity of 1300 lux resulted in higher growth (specific growth rate: 4% - 4.9% per day) compared to lower light intensity (1.2 lux), which only produced growth of 1.2% - 1.7% per day. This phenomenon has also been observed in fish larvae, for instance, gilt-head bream, *Sparus aurata*, rabbitfish, *Siganus sutor* (Fourooghifard et al., 2020), cod, *Gadus morhua*, chub mackerel, *Scomber japonicus* (Yoon et al., 2010), and walleye pollock, *Theragra chalcogramma* (Porter, 2001), all of which showed similar trends, where higher light intensity (more than 1000 lux) led to higher survival rates.

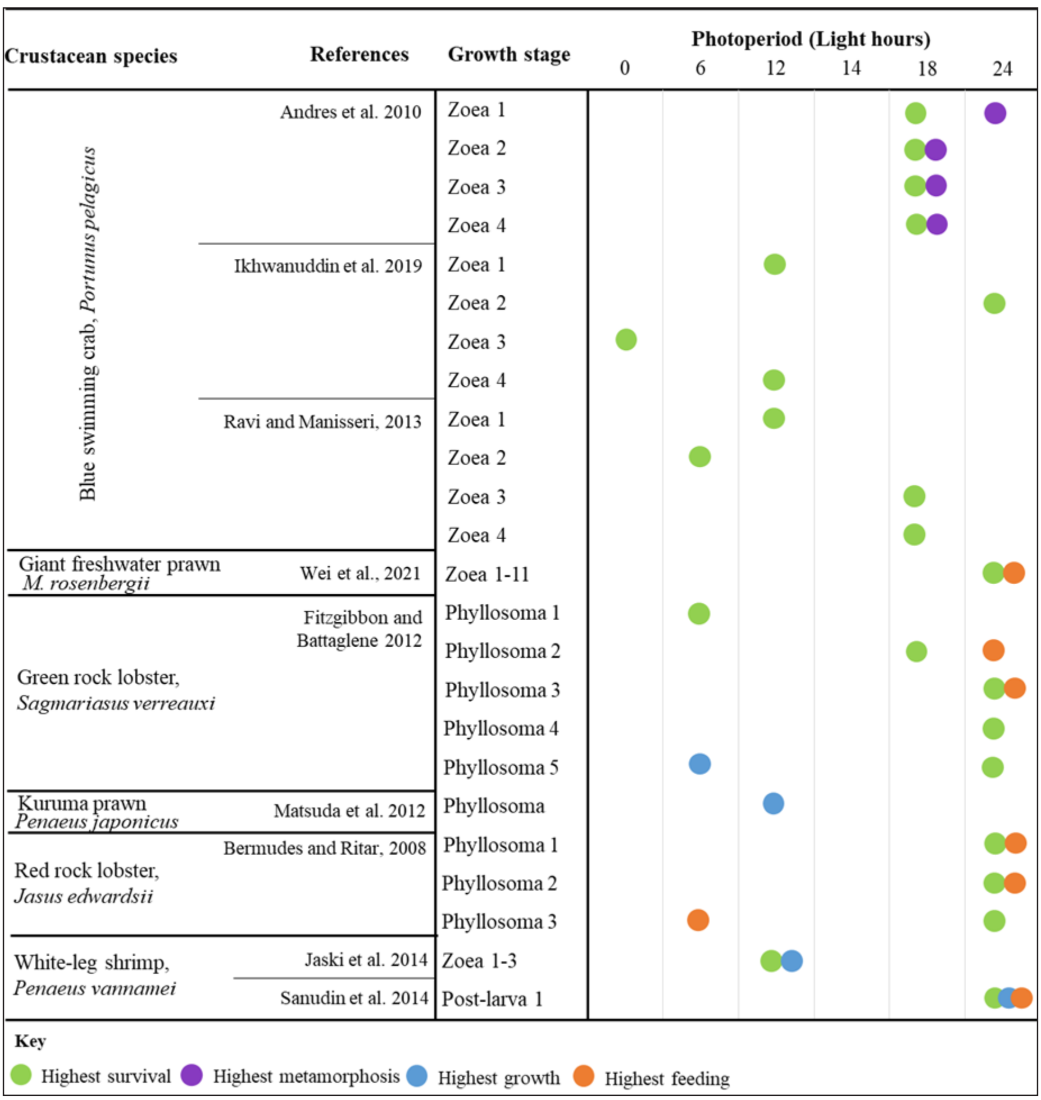

Figure 1. Effect of photoperiod on survival, metamorphosis, growth and feeding of crustacean larvae

Regarding the effect of light spectrum on crustacean larvae, Chen et al. (2022) reported that juvenile crabs reared under blue (460 nm) and cyan (510 nm) spectra exhibited higher moulting rates and lower oxidative stress. The transition of benthic crabs during recruitment from planktonic larvae suggests that juvenile crabs grow optimally under blue light, as blue wavelengths penetrate deeper, reaching the benthic zone (Villamizar et al., 2014). Although studies on the effect of light spectrum on crustacean larvae are limited, it is expected that larvae would perform better under white light, as crustacean larvae typically inhabit the upper water column near the surface. This expectation is supported by Wei et al. (2021) found that larvae of the giant freshwater prawn had higher survival (56%) and metamorphosis rates when reared under white light, whereas larvae exposed to red light showed lower survival (29%) and no metamorphosis. Similar findings have been reported in fish larvae, for example, zebrafish, *Danio rerio* (Villamizar et al., 2011), and goldfish, *Carassius auratus* (Imanpoor et al., 2011), exhibited better growth and feeding activity under white light, while larvae reared under green, yellow, or red light demonstrated reduced feeding activity, slower growth, and higher mortality.

How Light Affects Crustacean Larvae: Compound Eyes, Feeding, and Hormonal Mechanisms

Crustacean larvae are equipped with a larger compound eye as primary visual organs, and this eye consists of clear layers, which seems to be an evolutionary adaptation which is important for camouflage (Mishra et al., 2006; Cronin et al., 2017). The compound eye is comprised of a rounded cluster of small units called ommatidia, and each unit is able to function independently. The number of ommatidia increases with larval stage as a new unit of ommatidia is added along the anterior edge of the eye, hence increasing the larval eye size (Mishra et al., 2006). There is a dense area of light-sensitive cells in an ommatidium, known as the rhabdom, which plays an important role as stimuli in detecting and responding to light, creating phototactic behaviour. Since the ability to observe in dark condition are limited, most of crustacean larvae spend their entire larval stage in the upper water column (Mishra et al., 2006).

Light plays a major role in feeding for most crustacean larvae, as they are visual feeders that rely primarily on sight for foraging behaviour (Yoon et al., 2010). During early developmental stages, other complex sensory organs important for foraging remain underdeveloped (Sanudin et al., 2014). A minimum light intensity is necessary for crustacean larvae to exhibit normal hunting behaviour, and below this threshold, larvae are unable to detect or capture prey (Boeuf and Bail, 1999). This incidence has been demonstrated previously in the larvae of crab, shrimp, prawn and lobster, as summarised in Figure 1. Under extended photoperiod, light stimulates prey-capture activity, increasing feeding rate, and improving larval growth and survival (Imanpoor et al., 2011). For example, a previous study showed that in laboratory or hatchery settings, both prey (e.g., rotifers and *Artemia*) and crustacean larvae exhibit phototactic behaviour and accumulating in the water surface area, thus increasing the predation success of crustacean larvae (Downing & Litvak, 1999; Villamizar et al., 2011).

One possible hormone involved in light response in crustacean larvae is melatonin (N-acetyl-5-methoxytryptamine). Despite the limited information regarding melatonin in the crustacean larvae, there was evidence indicating the presence of melatonin in the eyestalk of mud crab, *S. paramamosain*, suggesting the role of this hormone in response to light (Chen et al., 2022). Light condition suppresses activity of enzymes such as arylalkylamine N-acetyltransferase (AA-NAT), which play a role in melatonin synthesis. Under darkness condition, AA-NAT is able to synthesise melatonin. In the presence of melatonin, nitric oxide synthase activity is inhibited, stimulating the synthesis of ecdysteroids (Villamizar et al., 2011). Then, ecdysteroids stimulates secretion of methyl farnasoate which plays a role in the growth of crustaceans (moulting) (Chen et al., 2022). Overall process shows that the growth of crustacean larvae occurs during the night or in dark conditions. A shorter dark period (e.g., 4 hours) is likely sufficient for melatonin secretion for promoting moulting in crustacean larvae, but a longer photoperiod (e.g., 18 hours) is necessary to ensure sufficient feeding to provide the energy requirements for larval growth at night. Previous studies indicate that larvae of blue swimming crab, green rock lobster, red rock lobster and white-leg shrimp had higher growth under longer photoperiod with successful metamorphosis reaching up to 80% (Andrés et al., 2010; Bermudes & Ritar, 2008; Fitzgibbon & Battaglene, 2012; Sanudin et al., 2014). Besides, other hormone potentially related to circadian rhythms in crustacean larvae is PDH-II (pigment-dispersing hormone II), since this hormone plays a role in pigment migration in the eye, which affects phototaxis behaviour and vertical migration of larvae. Huang et al. (2014) found that the PDH-II was upregulated under bright light at 0900-1500 but reduced under low light levels at 1800-0600, suggesting the role of this hormone in promoting phototaxis behaviour.

CONCLUSION, GAP STUDIES AND FUTURE PROSPECT

In conclusion, this short review provides insight into the light effect on crustacean larvae. Longer photoperiod up to 18 hours, higher light intensity and white light spectrum could improve growth and survival of crustacean larvae. In the future, further studies on light intensity and light spectrum are necessary to be conducted due to scarce information. Also, the mechanism of light effect on crustacean larvae, primarily in terms of gene expression, hormones and antioxidant properties, should be investigated. The use of recent technology, such as transcriptomics, may be important to reveal gene and hormonal pathways in crustacean larvae that are affected by light. In aquaculture, one of the main challenges in crustacean aquaculture is to obtain a consistent supply of larvae (seeds). Adjusting light conditions in commercial settings could significantly improve culture efficiency, especially during the prolonged phyllosoma rearing phase. With a better understanding of light's effects on crustacean growth, the duration of the phyllosoma phase, currently lasting up to 12 months, might be reduced to 6 months in laboratory or hatchery conditions.

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CONFLICT OF INTEREST

The authors declare no conflict of interest. The funders had no role in the design of the study, in the collection, analyses, or interpretation of data, in the writing of the manuscript, or in the decision to publish the results.

AUTHOR CONTRIBUTIONS

Ariffin Hidir designed the study, gathered information, analysed data and drafted the paper. Mohd Amran Aaqillah-Amr and Hongyu Ma reviewed the paper. Mhd Ikhwanuddin drafted, reviewed the paper and was involved in funding acquisition, project administration, and supervision.

ETHICAL APPROVAL

Ethical approval is not required as no experiments were conducted in the production of this research paper.

DATA AVAILABILITY STATEMENT

All data supporting the findings of this study are included within the paper. No additional data are available.

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