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Phototactic Response of Seurukan (*Osteochilus sp.*) to Different LED Light Spectra

Respon Fototaksis Ikan Seurukan (*Osteochilus sp.*) terhadap Perbedaan Spektrum Warna Cahaya Lampu LED

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Abstract

The use of conventional lamps in light fishing activities entails low energy efficiency and environmental risks, creating a need for Light Emitting Diode (LED) innovation. However, data on the phototactic response of local freshwater fish such as Seurukan (*Osteochilus sp.*) to LED color spectra remain very limited. This study aimed to analyze and evaluate the positive phototactic preference of Seurukan fish toward five LED light spectra (red, green, blue, yellow, and white). A laboratory experiment was conducted using the preference zone method in a light-isolated aquarium divided into three zones (Zone 1: light exposure, Zone 2: transition, Zone 3: dark). Twenty test fish (5–6 cm) were observed for their presence in Zone 1 for 15 minutes per color treatment at 1-minute intervals, and the data were analyzed using one-way ANOVA followed by a post-hoc test. The results showed that different LED color spectra significantly affected positive phototactic preference ($F = 13.66$; $p < 0.001$). The green LED spectrum elicited the highest preference at 65.0% (mean of 13.00 fish), followed by white (47.7%), yellow (42.3%), blue (24.0%), and lowest in red (8.0%). Tukey's HSD test indicated that the response to green LED did not differ significantly from white and yellow LEDs, but differed significantly from blue and red LEDs, attributable to the green-shifted vision physiological adaptation of the freshwater fish retina. These findings provide a biological basis for designing selective, energy efficient LED based freshwater fishing devices and for domestication management.

Keywords: *Osteochilus sp.*, light fishing, green-shifted vision, visual preference.

Abstrak

Pemanfaatan lampu konvensional pada aktivitas light fishing menimbulkan masalah efisiensi energi yang rendah serta risiko merusak lingkungan, sehingga diperlukan inovasi Light Emitting Diode (LED). Namun, data mengenai respons fototaksis ikan air tawar lokal seperti ikan Seurukan (*Osteochilus sp.*) terhadap spektrum warna LED masih sangat terbatas. Penelitian ini bertujuan untuk menganalisis dan mengevaluasi tingkat preferensi fototaksis positif ikan Seurukan terhadap lima spektrum warna cahaya LED (merah, hijau, biru, kuning, dan putih). Metode yang digunakan adalah eksperimen laboratorium dengan preference zone method menggunakan akuarium terisolasi cahaya yang dibagi menjadi tiga zona (Zona 1: paparan cahaya, Zona 2: transisi, Zona 3: gelap). Sebanyak 20 ekor ikan uji (5–6 cm) diamati keberadaannya di Zona 1 selama 15 menit per perlakuan warna dengan interval 1 menit, lalu data dianalisis menggunakan ANOVA Satu Arah dan uji lanjut. Hasil penelitian menunjukkan bahwa perbedaan spektrum warna LED berpengaruh signifikan terhadap preferensi fototaksis positif ($F = 13,66$; $p < 0,001$). Spektrum LED hijau menghasilkan preferensi tertinggi sebesar 65,0% (rerata 13,00 ekor), diikuti LED putih (47,7%), kuning (42,3%), biru (24,0%), dan terendah LED merah (8,0%). Uji Tukey HSD mengindikasikan respon LED hijau tidak berbeda nyata dari LED putih dan kuning, tetapi berbeda signifikan dari LED biru dan merah akibat adaptasi fisiologis green-shifted vision retina ikan air tawar. Implikasi penelitian ini memberikan acuan biologis dalam perancangan alat bantu penangkapan ikan tawar berbasis LED yang selektif dan hemat energi serta manajemen domestikasi.

Kata Kunci : *Osteochilus sp.*, light fishing, green-shifted vision, preferensi visual.

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1. Introduction

The use of artificial light in fisheries activities, both in commercial capture operations and in studies of aquatic animal behavior, has long served as a crucial technological pillar for manipulating fish behavior. The tradition of light fishing in Indonesia generally relies on the biological tendency of certain pelagic and freshwater fish to move toward a light source (Baswantara *et al.*, 2020). This light-induced orientation behavior is scientifically known as positive phototaxis (Cahyadi & You, 2017). In field operations, fishers commonly rely on conventional high-intensity lamps, such as fluorescent, mercury, or pressure (petromax) lamps, as these are considered effective for aggregating large schools of aquatic organisms around the fishing area (Susanto *et al.*, 2017). However, dependence on these conventional lamp types leaves several serious classical problems, including limited fuel oil availability, low energy conversion efficiency, ultraviolet radiation that is harmful to juveniles, and high accumulation of heat energy released into the environment. To address these operational shortcomings, the trend in fisheries lighting technology has begun shifting toward Light Emitting Diodes (LEDs). LEDs are regarded as a state of the art, environmentally friendly solution owing to their considerably longer technical lifespan, ability to operate at low voltage, and high energy efficiency without raising the temperature of the surrounding water.

The phototactic behavioral response and physiological adaptation of fish to light exposure are fundamentally correlated with the histological capacity of the retina to recognize spectral characteristics, including color dimensions and light dark gradation (Cahyadi & You, 2017). Each fish species is equipped with distinct visual capacity and cellular structure, resulting in unique interpretations of color and wavelength penetration within the water column (Susanto *et al.*, 2017). Several empirical studies confirm that light color spectrum stimulation not only directs fish migratory movement but also influences other physiological developmental aspects, such as daily behavioral dynamics, body pigmentation quality, growth rate, spawning performance, and stress levels (Haq *et al.*, 2022; Nisa *et al.*, 2022; Priosembodo *et al.*, 2020; Thaib *et al.*, 2025). In the context of capture-technology applications, the selection of particular monochromatic color combinations (such as the blue spectrum) has been shown to attract and retain fish schools under illumination for considerably longer than exposure to broad-spectrum white light (Baswantara *et al.*, 2020; Susanto *et al.*, 2017).

Although studies on the effectiveness of LED spectra for marine fish commodities have been widely published, comparable observations targeting freshwater species, particularly local fish, remain very limited. Seurukan (*Osteochilus* sp.) is a native freshwater fish species of considerable ecological importance and promising economic potential within its distribution range. Biologically, this fish group is classified as a highly visually active organism in responding to the dynamics of its aquatic environment. The spatial movement patterns, predator avoidance, and foraging activity of Seurukan fish are strongly dependent on visual orientation toward the light transmitted through their habitat. Therefore, identifying how

Seurukan fish determine positional preference in response to light-color stimulation constitutes fundamental information on fish behavioral biology.

To date, no scientific literature has presented comparative data on the phototactic response of Seurukan fish to variations in monochromatic LED light spectra. The question of which spectrum most effectively stimulates positive phototaxis whether short wavelength spectra such as blue and green, long-wavelength spectra such as red and yellow, or a broad spectrum such as white constitutes the research gap underlying the urgency of this study. Empirical knowledge of the boundaries of this visual preference zone not only contributes to the body of knowledge on fish behavior but also plays a practical role in designing selective fishing devices and in managing the domestication of organisms in freshwater aquaculture environments.

Based on the foregoing rationale, this study was initiated using a laboratory experimental approach with the preference zone method. The study focused on observing, quantifying, and evaluating the level of attraction and phototactic response of Seurukan fish to five different LED light spectra, namely red, green, blue, yellow, and white. Through measured testing based on a specific time duration, the output of this research is expected to map the LED light-color spectrum most effective in attracting the attention of Seurukan fish, which can subsequently be recommended as a basis for developing appropriate fisheries technology.

2. Materials and Methods

2.1. Subjects and Location

This experimental study was conducted over three consecutive days at the Hatchery of Universitas Teuku Umar. This limited duration was chosen to ensure that the test organisms remained in optimal physical condition and to minimize bias arising from spatial confinement during the observation process (Susanto *et al.*, 2017). The test organisms used in this study were 20 individuals of Seurukan (*Osteochilus* sp.) with a uniform body length range of 5–6 cm. This size homogeneity was critical to avoid visual bias caused by differences in visual organ maturity or migratory capacity among individuals (Susanto *et al.*, 2017). Prior to testing, all fish samples were acclimatized in holding containers for a period of time to ensure that the fish had adapted to the laboratory water conditions and were free of post-transport stress.

2.2. Research Method

The main equipment used consisted of a single aquarium unit measuring 50 cm in length, 30 cm in width, and 35 cm in height. As a phototactic stimulus, five types of LED (Light Emitting Diode) lamps emitting different monochromatic and broad-spectrum colors were prepared, namely red, green, blue, yellow, and white LEDs (Cahyadi & You, 2017). Other supporting equipment included a stopwatch for monitoring duration, stationery for conventional data recording, and sheets of opaque black plastic serving as an external light isolator.

Experimental Design and Test Container Setup. This study applied a laboratory experimental approach adopting the preference zone method without any physical partition within the water medium. The aquarium was conditioned to create a fair orientation space for fish movement. All aquarium walls (the

left, right, and back sides, and the bottom) were tightly covered with opaque black plastic. This isolation step was essential to eliminate the entry of external light and to prevent reflection or glare bias on the glass that could misdirect the fish's positional orientation.

The 50 cm-long aquarium was then visually divided into three imaginary zones using small tape markers attached to the outside:

- Zone 1 (Light Exposure Area): a 15 cm long area measured from the aquarium end where the LED lamp was installed. This zone represents the positive phototaxis response area.
- Zone 2 (Transition Zone): the middle area of the aquarium bridging the illuminated and neutral regions.
- Zone 3 (Neutral/Dark Zone): the area at the opposite end from the lamp position, which tends to have minimal light intensity or darkness units.

2.3. Testing Procedure and Data Analysis

Testing was carried out by observing the response of the Seurukan fish group to each LED light color in turn. At the beginning of each test, all test fish (20 individuals) were placed into the aquarium and left undisturbed without illumination for several minutes as an environmental calibration phase. The first LED lamp was positioned directly at the side of Zone 1, with the distance to the water surface kept consistent. After the lamp was switched on, observation was carried out for a total duration of 15 minutes per color spectrum. The number of fish individuals present in Zone 1 was counted at regular 1-minute intervals (from minute 1 to minute 15). Once completed, the lamp was switched off and the aquarium was returned to dark conditions to neutralize the fish's visual memory before proceeding to the next color.

The Positive Phototaxis Preference Percentage (P) was calculated using the following formula:

$$P = \bar{x}^{Zone\ 1} / N \times 100\%$$

Notes:

P = positive phototaxis preference percentage (%)

$\bar{x}^{Zone\ 1}$ = mean number of fish present in the target zone (light source)

N = total population of test fish in the aquarium.

The data obtained were statistically analyzed using one-way ANOVA followed by Tukey's HSD post-hoc test at a 95% confidence level ($\alpha = 0.05$).

3. Results and Discussion

The laboratory experimental results revealed a fairly marked difference in the level of attraction (positive phototaxis) of the Seurukan (*Osteochilus* sp.) group toward the five LED light spectra tested. Measurement of fish presence in Zone 1 (the target light-exposure area, 0–15 cm radius from the LED source) yielded variation in the mean accumulation values and the positive phototaxis preference percentage (P), as presented in Table 1.

Table 1.

Total Mean presence of Seurukan fish in Zone 1 and positive phototaxis preference percentage based on different LED light spectra

LED Color	λ (nm)	Mean Count	Preference (%)	SD
Blue	~460–475	4.8	24.0%	30.07
Red	~620–635	1.6	8.0%	9.41
Yellow	~580–595	8.47	42.3%	28.78
White	Broad spectrum	9.53	47.7%	22.11
Green	~515–530	13	65.0%	18.61

Note: total test fish population per trial (N) = 20 individuals; observation was conducted for 15 minutes with a 1-minute recording interval.

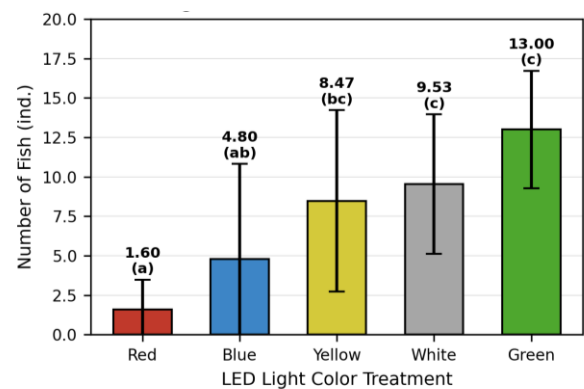


Figure 1. Mean number of fish in the target zone (Zone 1)

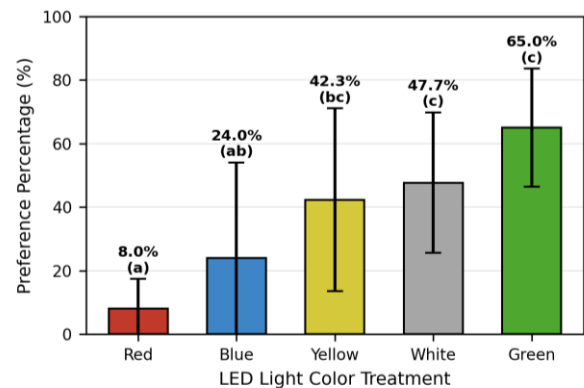


Figure 2. Percentage of positive phototaxis preference

Based on these quantitative data, the green LED spectrum recorded the highest positive phototaxis preference percentage at 65.0%, with an average of 13 fish consistently aggregating around the light source. The second position was occupied by white LED with a preference value of 47.7% (9.53 fish), followed by yellow LED at 42.3% (8.47 fish). In contrast, the short-wavelength spectrum (blue LED) and the long-wavelength spectrum (red LED) recorded preference values of only 24.0% and 8.0%, respectively.

The post hoc test results identified that green LED (~515–530 nm) produced the highest positive phototaxis preference percentage, at 65.00% (mean of 13.00 fish in Zone 1). This response level did not differ statistically significantly from white LED (47.67%) and yellow LED (42.33%), but differed significantly from blue LED (24.00%) and red LED (8.00%). This finding is consistent with the studies of Xu *et al.* (2022) and Wang *et al.*

(2026), which reported a dominant tendency toward positive phototaxis in Cyprinidae fish under the green spectrum. This mechanism is closely related to the physiological adaptation of the visual organ. Most freshwater teleost fish (*Osteichthyes*) possess visual pigments in retinal cone cells (*rhodopsin* and *porphyropsin*) with a peak absorption wavelength (λ^{max}) in the range of 495–530 nm, corresponding to the green spectrum (Loupatty, 2012). This causes green light stimulation to be received most optimally by the fish visual nervous system. Meanwhile, white LED does not have a single wavelength but rather a broad spectrum encompassing green and blue components. The presence of the green spectrum within white LED explains why it still retains a relatively high attractiveness (47.7%) (Nguyen, 2018). Red light, in contrast, has a long wavelength (~620–635 nm) with the lowest photon energy within the visible spectrum. Within the water medium, red light undergoes the fastest attenuation and is perceived as a “dark zone” or an unfamiliar stimulus to the fish eye, resulting in universally the lowest phototactic response (Nguyen, 2018; Wang *et al.*, 2026).

Several previous studies (particularly on lift-net or squid fishing gear in open seas) have instead reported that blue LED elicits the highest response (Khairul *et al.*, 2017). This discrepancy is attributable to several ecological and methodological factors. Freshwater or shallow-water environments are rich in Colored Dissolved Organic Matter, which absorbs short (blue) wavelengths. Consequently, the eyes of freshwater fish such as *Osteochilus vittatus* have evolved a shift in visual sensitivity toward the green spectrum (green-shifted vision) (Syam & Satria, 2017; Hölker *et al.*, 2023). Conversely, clear seawater refracts the blue spectrum the farthest, so that deep-sea pelagic fish generally possess visual pigments specifically adapted to the blue spectrum (~470–480 nm). Considering the scale and depth of the test medium, in the shallow laboratory aquarium/container scale used in this study, light penetration was not a limiting factor. In contrast, in open-sea field trials, the greater penetration depth of blue LED often attracts fish from greater distances compared with other colors (Khairul *et al.*, 2017). In addition, feeding behavior also plays a role. Some fish species approach green light not solely due to a direct phototactic response, but as a secondary response to the aggregation of zooplankton and natural food organisms that react positively to bright/green light (Pandeiro *et al.*, 2022).

4. Conclusion

LED light-color treatment had a statistically significant effect on the level of positive phototaxis preference of Seurukan (*Osteochilus* sp.) ($F = 13.66$; $p < 0.001$). Green LED (~515–530 nm) was the most effective spectrum, with a preference percentage of 65.0%, followed by white (47.7%), yellow (42.3%), blue (24.0%), and red (8.0%). The strong attraction to green light is driven by the green-shifted vision physiological adaptation characteristic of the freshwater fish retina. These results recommend the use of green or white LEDs as the primary attractor in the development of energy-efficient, ecologically based freshwater fishing devices.

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