Fish behavior characterization with an RGB-LED intensity based on pulse width modulation (PWM) system in fixed lift net

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Abstract. The application of the Red-Green-Blue Light-Emitting Diode (RGB-LED) based on Pulse Width Modulation (PWM) with a microcontroller system is considered a possible measure for effectiveness in the fixed lift net. The effectiveness of a fishing lamp can be determined from how fish attract light and gather in the zone of catching lift net that can be monitored using fish behavior monitoring. This study aimed to investigate the light intensity of the RGB-LED and the distribution of fish behavior in the lift net. An experiment used four kinds of PWM intensity, 250 PWM, 95 PWM, 20 PWM, and 5 PWM. Fish behavior and distribution were monitored under there light intensity zone: center, main, and influence zone both spatial and temporal. The 250 PWM had dispersed intensity distance, whereas the 95 PWM, 20 PWM, and 5 PWM had focused more on the front. Overall, schooling fish was dominated in the main zone (1x10⁻⁶ W cm⁻²-3x10⁻⁷ W cm⁻²). The highest value light intensity was found on 95 PWM with accounted for 48.67% because the fish schooling adaptation is relatively consistent. These results suggest that fishing enterprises can improve catching performance by using light intensity 95 PWM.

1. Introduction
Research related to the use of lighting technology with the type of LED as a tool for light fishing has developed rapidly in Indonesia. One of the evolving LED technologies is the High Power Lide Light-Emitting Diode (HPL-LED) by Sumardi et al. [1]. The research carried out in an attempt to examine the intensity of the 50 watts HPL-LED as basic information that determines the shape of the design of fishing aids that act as fish attractors. As such, the use of LED offers several advantages, including color light, light intensity, and brings enormous energy saving [1-3].

In addition to a brief development of RGB-LED was conducted by Sumardi et al. [4], the innovations in the intensity of RGB-LED with a microcontroller-based pulse width modulation (PWM) system in a fixed lift net. The RGB-LED is LED lights with different colors, red, green, and blue, whereby the combination was set with different intensities in each color and operated simultaneously. PWM is a system used as automatic control and adjustment of LED during operation fixed lift net [5-10]. Therefore, RGB-LED innovation was designed to attract significant fish targets.
The application of the RGB-LED with varying intensity on fixed lift net fisheries confirmed that it can help fishermen concentrate the fish at a more effective. The use of a microcontroller acts as a regulator of light intensity, which is more stable compared to dimmers [4, 11, 12]. However, the results indicate that RGB-LED by Sumardi et al. [4] has shortcomings where no information data about the great intensity for the catching process and fish behavior to the intensity RGB-LED.

The research was then continued by Sugandi et al. [13] which determines the intensity of the RGB-LED for hauling process and investigate the response fish based on fish behavior. The methods were included: a). measurement of the intensity RGB-LED in the air and underwater medium, b). hydro-acoustic recording using side imaging sonar, c). measurement of the environmental parameters (i.e., pH, salinity, and temperature), and d) identification of the fish target. Observation result on LED RGB application in this field, the highest intensity of RGB-LED was 250 PWM, and the lowest intensity was 5 PWM. Nevertheless, further investigation is incomplete while using RGB-LED in one place, and the treatment is not yet in the season. This study was conducted on Bokor Island, Kepulauan Seribu, with a measure of fixed lift net (12 x 12-m length and width), 21 m in water depth. Indicators of RGB-LED technology that can be used by fishermen are the availability of additional data information and the results in different places and periods. Therefore, this paper inspects some studies to investigate the light intensity of the RGB-LED and the distribution of fish behavior in the fixed lift net by conducting the test in Banten Bay, which is 10 x 10-m of length and width, and 7 m in water depth [14, 15].

2. Methods
Experiments were conducted in December 2019 at Banten Bay, West Java with the coordinate position of 5° 58’ 44” LS and 106° 10’ 15” BT (Figure 1).

![Figure 1. Map of the research site in the Banten Bay.](image-url)

2.1 Experimental condition
The experimental set up was previously described by Sugandi et al. [13], Susanto et al. [16], and Kairul et al. [17]. Briefly, each treatment of the two experiments was performed using 4 replicates. (4 x 4 experiment PWM), which used several treatment i.e RGB-LED 250 PWM (peak wavelength: 48.7
W m\(^{-2}\)); 95 PWM (peak wavelength: 40.2 W m\(^{-2}\)); 20 PWM (peak wavelength: 38.8 W m\(^{-2}\)) and 5 PWM (peak wavelength: 37.2 W m\(^{-2}\)). Lamps were built using the RGB-LED on the armature (320 x 220-mm) with a microcontroller and powered by 12 V DC supply.

Experiments through field observations started at 19:00 and ended at 04:00. Each light condition kept for 120 min for the response of fish behavior (90 min for a setting session and 30 min for hauling session). Measurement performed at a distance of 1 x 1 m from the light point for both vertically and horizontally (Figure 2). This study was conducted in 2 stages. The first step in the light intensity experiment (LI) was measured by ILT 5000 research radiometer is used to investigate the illumination distribution underwater. In the subsequently performed fish behavior was conducted with the imaging sonar system. The primary purpose is to determine the optimum settings of system parameters (i.e., range, stepping speed, and gain). Validation of intensified fish behavior was conducted simultaneously through the use of an underwater camera.

![Figure 2. The measurement of the light intensity RGB-LED with PWM in underwater, whereas a) is fixed lift net; b) is RGB-LED lamp; c) is the ILT 5000 Research Radiometer; d) light sensory; e) is the side imaging sonar; f) is horizontal length which 10 m depth; and g) is vertical length 6 m depth.](image)

2.2 Data analysis

The light intensity distribution was analyzed using the Surfer Software version 13 was monitored under three light intensity zone (center, main, and influence zone) both in the spatial and temporal. The influence zone (IZ) is the area of light in the outside fixed lift net, the main zone (MZ) is the area of light in the fixed lift net, and the center zone (CZ) is the area which a strong light [13]. Based on the vertically and horizontally, the main and center zone are the areas of light contained within the fixed lift net, namely the catchable area (CA) (Figure 3).

The proportion of fish schooling in each zone was analyzed using Image-J, which an open-source analysis software with data macro tools for processing and analyzing digital images with patterns [18]. Measurement of the proportion of fish schooling was carried out using a formula by Alhosseini et al. [19]:

\[
P = \left(1 - \frac{n}{N}\right) \times 100 \%
\]

Briefly, \(n\) are representing white image, \(N\) is a total image and \(P\) are the total area of proportion.
Figure 3. The zoning is based on the light intensity with PWM values

3. Results and discussions
3.1 Light intensity
The characteristic pattern of light intensity between 250 PWM, 95 PWM, 20 PWM, and 5 PWM showed differences in distribution. First, 250 PWM (a high intensity value) was used in the setting process and each hauling process with a moderate intensity of 95 PWM and a low intensity of 20 and 5 PWM. As shown in Fig.4, 250 PWM had dispersed intensity distance. In particular, as shown in Fig.5 that the 95 PWM, 20 PWM, and 5 PWM had focused more on the front. Thus, the light intensity with PWM was monitored under there light intensity zone: center, main, and influence zone both vertically and horizontally.

The light intensity RGB-LED with PWM was designed in such a way that the difference in the distribution light intensity in all mediums is minimized. The specific light intensity had a small distribution in water, approximately 120°. A small distribution can increase the concentration of light intensity at a certain point [10, 20]. Therefore, in this study, the distribution light intensity RGB-LED with PWM could increase the fish concentrated on a certain radius during operating fixed lift net.

Figure 4. Light distribution of treatment diagrams in the setting process with 250 PWM vertically and horizontally.
3.2 Distribution of fish behavior in the lift net

The application of RGB-LED with PWM also affected the pattern of schooling fish behavior. Based on spatial and temporal analyses on position and density of fish targets, it was concluded that fish movement behavior in the scanned area followed in corridors with significant different passage rates. As shown in Fig. 6, 250 PWM in the setting process (0-90 min) reported that schooling fish had spread

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**Figure 5.** Light distribution of treatment diagrams in the hauling process with vertically and horizontally
in radius 4-5 m depth, the main zone \((5 \times 10^{-7} \text{ W cm}^{-2} - 1 \times 10^{-7} \text{ W cm}^{-2})\) with accounted for 46.67\% (temporal) and spatial of 44.33\%. Furthermore, in the hauling process (100-120 min) with 95 PWM, 20 PWM, and 5 PWM had different patterns. Figure 6 shows the 95 PWM the schooling fish had a radius concentrated 1-2 m depth, the main zone \((1 \times 10^{-6} \text{ W cm}^{-2} - 3 \times 10^{-7} \text{ W cm}^{-2})\), and the total amount of temporal (41.00\%) and spatial of 48.67\%. As indicated by the 5 PWM results, the distribution of schooling fish had relatively spread radius 1-3 m depth, the influence zone \((7 \times 10^{-7} \text{ W cm}^{-2} - 3 \times 10^{-7} \text{ W cm}^{-2})\) with ranged 37.00\% (temporal) and 42.23\% for spatial (Figure 7). In addition, the treatment 5 PWM shows that schooling fish had radius 2-3 m depth, the main zone \((3 \times 10^{-7} \text{ W cm}^{-2} - 1 \times 10^{-7} \text{ W cm}^{-2})\), approximately 45.00\% (temporal) and 34.00\% (spatial) (Figure 9).

The results of the experiment show that the light intensity RGB-LED with 95 PWM is useful, which induces a good light adaptation and relatively constant. Thus, it indicates that the target fish provides a faster and more consistent adaptation response, so the behavior of the fish that occurs is relatively constant [21, 22].

Figure 6. The distribution of the schooling fish patterns with 250 PWM in the setting process from 0 to 90 min
Figure 7. The distribution of schooling fish patterns with 95 PWM in the setting process from 100 to 120 min.
**Figure 8.** The distribution of the schooling fish patterns with 20 PWM in the setting process from 100 to 120 min

**Figure 9.** The distribution of the schooling fish patterns with 5 PWM in the setting process from 100 to 120 min
4. Conclusion
The conclusion from this research that the 250 PWM had dispersed intensity distance, whereas the 95 PWM, 20 PWM, and 5 PWM had focused more on the front. Overall, the schooling fish was dominated in the main zone (1x10⁻⁶ W cm⁻²-3x10⁻⁷ W cm⁻²). The highest value light intensity was found on 95 PWM with accounted for 48.67% because the fish schooling adaptation is relatively consistent.

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