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The Application of LED-RGB Lights on Fish Aggregating Devices in Ternate

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ABSTRACT

Fish aggregating devices (FADs) play a crucial role in fisheries by concentrating pelagic and demersal fish, thereby increasing catch efficiency. However, their performance can be further optimized through technological enhancements, such as artificial lighting systems. To explore this potential, this study investigated the effectiveness of LED-RGB lights on fish aggregating devices (FADs) in attracting fish and improving catch rates in Ternate Waters. This study investigated the effects of LED-enhanced Fish Aggregating Devices (FADs) on gillnet fishing efficiency. Experimental trials were conducted by deploying gillnets alongside FADs equipped with programmable RGB-LED lights. The light intensity measurements revealed significant differences among the LEDs. Red LEDs exhibited stable intensity (53–64 lux), Green LEDs showed moderate variation (61–84 lux), and Blue LEDs had the highest and most variable intensity (114–212 lux). Observations of fish behavior under RGB lights indicated that fish distribution and depth varied significantly by light color. Blue LEDs attracted fish to deeper depths (9–12m), Green LEDs concentrated fish at medium depths (4–10m), and Red LEDs were effective at shallower depths (1.5–3.5m). Catch composition analysis demonstrated a significant dominance of Indian scad (*Decapterus russelli)*, which comprised 88% of the total catch, while rainbow runner (*Elagatis bipinnulata*), and bigeye scad (*Selar crumenophthalmus*) represented 8 and 4%, respectively. These findings suggest that LED-RGB lighting on FADs can optimize fishing strategies by targeting fish at specific depths and enhancing selectivity.

INTRODUCTION

Fish aggregating devices (FADs) are widely used in tropical fisheries to concentrate pelagic fish species, enhancing catch efficiency and reducing fishing effort **(Widodo *et al*., 2020; Syari *et al*., 2023)**. In Ternate, Indonesia, where small-scale fisheries play a vital role in local livelihoods, FADs serve as critical tools for sustaining fish production. However, conventional FADs have limitations in their ability to attract and retain fish, particularly under varying oceanographic conditions. Recent advancements in artificial lighting technology, particularly LED-RGB (Red, Green, Blue) systems, offer promising potential to optimize FAD performance by exploiting fish phototactic behavior **(Fatmawati *et al*., 2020)**. The use of LED-RGB lights on FADs offers the potential to strengthen the role of FADs as fishing aids. Research on the use of LED-RGB lights has been conducted by **Fatmawati (2020)**, **Sumardi (2020)**, and **Turnip *et al*. (2022)**, which shows that the use of LED-RGB lights can attract more fish compared to other colors.

Research has shown that the use of lights on FADs increases the catch percentage **(Laian *et al*., 2023; Zulkarnain *et al*., 2023)**. The production of FADs with light reached 1935.4kg higher compared to the catch on control FADs **(Zulkarnain *et al*., 2023)**. The utilization of light-assisted gillnet fishing gear around FADs has been reported to yield a multispecies catch composition, including Mackerel (*Decapterus macarellus*), Indian scad (*Decapterus ruselli*), skipjack tuna (*Auxis thazard*), Dorado (*Coryphaena hippurus*), and Squid (*Loligo* sp.) **(Afrisal *et al*., 2024)**. However, the effectiveness of specific light colors (Red, Green, Blue) varies depending on species-specific visual sensitivity, water depth, and light penetration **(Sudirman *et al*., 2020)**.

Although previous studies have demonstrated the potential of LED-RGB lights in enhancing fishing efficiency, their impact on fish aggregation dynamics in the waters of Ternate remains poorly understood. This knowledge gap is particularly relevant given the unique environmental conditions and species composition in the region. In local fisheries, gillnets are commonly deployed around FADs, but illumination is typically limited to conventional fluorescent lamps. While gillnet use in combination with FADs has shown moderate effectiveness, **Dollu *et al*. (2023)** reported a catch efficiency of 45.28%. However, the combined effect of LED-enhanced FADs and gillnet fishing efficiency has not been thoroughly investigated in Ternate.

Therefore, this study aimed to evaluate the influence of LED-RGB light colors (red, green, and blue) on fish aggregation behavior and gillnet catch efficiency in Ternate's FAD fisheries. It specifically addresses species-specific responses and seeks to identify optimal light deployment strategies to improve fishing performance and sustainability in the region.

MATERIALS AND METHODS

1. Study area

The research was conducted from June to August 2024, on fish aggregating devices (FADs) in Ternate, North Maluku (Fig. 1).

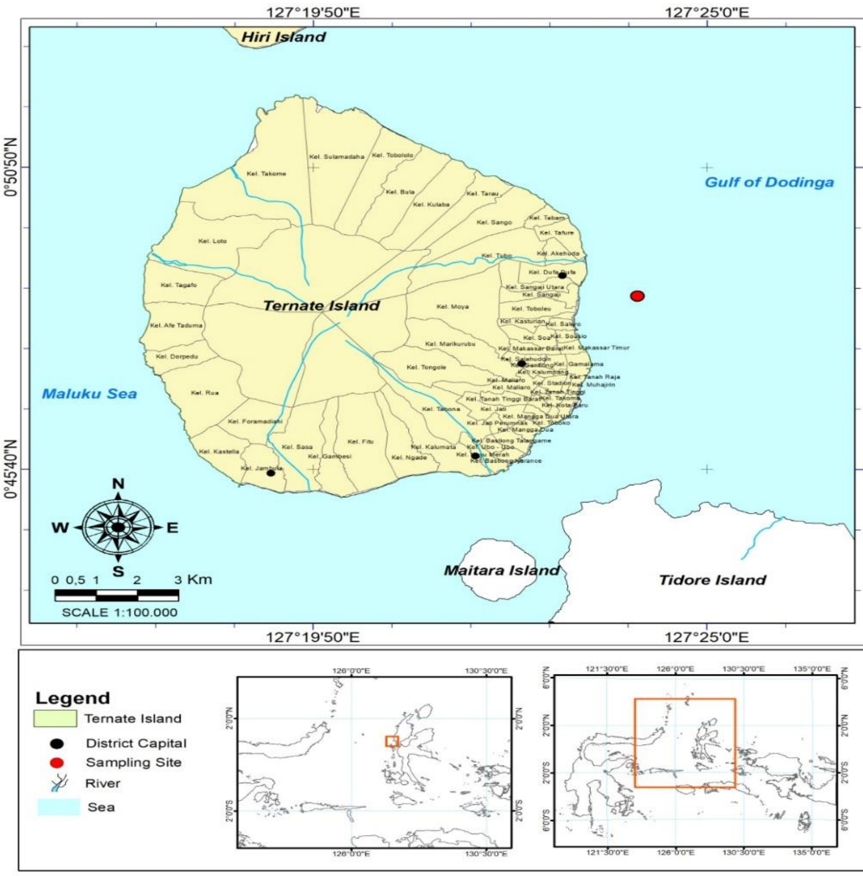

Fig. 1. Map of the research location in the Ternate Waters

2. Data collection

The study used an experimental fishing approach to evaluate the effectiveness of LED-RGB lights in attracting fish around fish aggregating devices (FADs), using gillnets as the primary fishing gear. LED-RGB lights were installed on the FADs at approximately 19:00 local time. During each trial, three light colors (blue, green, and red) were tested sequentially, with each color illuminated for 30 minutes. The total duration for the light exposure (setting session) was 90 minutes, followed by a 20-minute hauling session to retrieve the nets and assess the catch. The experiment was conducted in three main stages. The first stage involved measuring the luminous intensity of each RGB light color using a lux meter to determine light penetration in the water column **(Wisudo, 2002)**. In the second stage, the LED-RGB lights were activated on the FADs (starting with blue, followed by green, and then red) to observe fish behavioral responses to each color. These behavioral patterns were monitored using an underwater sonar system to detect fish presence, movement, and aggregation around the FADs during the illumination of each light color **(Fatmawati *et al*., 2020)**. In the third stage, gillnets were deployed around the FADs following the light exposure period to capture the aggregated fish. The resulting catch was analyzed to determine species composition, abundance, and the effectiveness of each light color in enhancing fishing success. This experimental design aimed to identify the most effective light color for attracting fish and to evaluate the potential of LED-RGB technology in optimizing gillnet fishing operations near FADs.

3. Data analysis

The data analysis in this study focused on two main components: fish behavioral observations around FADs and the catch composition from gillnet operations. Behavioral data were obtained through sonar recordings during the illumination of blue, green, and red LED lights. These observations were analyzed descriptively to compare patterns of fish presence, aggregation behavior, and proximity to the FAD during each light color treatment. For the catch data, analysis was conducted based on catch proportion:

$$Catch\ Propotion = \left(\frac{Number\ of\ individual\ fish\ of\ a\ species}{Total\ number\ of\ fish\ caught}\right) x\ 100\%$$

The total catch from gillnet operations was recorded and sorted by species. The proportion of each species in relation to the total catch was calculated to determine the selectivity and effectiveness of RGB lights and the results were presented as percentages.

RESULTS

1. Intensity of LED-RGB (Red, Green, Blue) lights

Based on the light intensity measurements, there were significant differences between Red, Green, and Blue LEDs (Fig. 2). The measurement results for the Red LED were relatively stable, with intensities tending to fall within the range of 53 to 64 lux. The highest value was achieved in the third trial with an intensity of 64 lux, while the lowest value of 53 lux was recorded in several other measurements. The differences in light intensity produced by the Red LED were not very significant, and it can be concluded that the Red LED has good stability in terms of light intensity.

The Green LED showed a greater variation in light intensity compared to the Red LED, with a range of 61 to 84 lux. The peak intensity occurred in the fourth trial with a value of 84 lux, while the lowest value of 61 lux was recorded in the first, second, and fifth trials. The significant differences between these measurements indicate that the Green LED is more sensitive to environmental conditions or variations in the measurement process, resulting in more variable intensities.

Meanwhile, the Blue LED produced the highest light intensity compared to the other LEDs, with a value range of 114 to 212 lux. The peak value was recorded in the third trial with an intensity of 212 lux, which is the highest intensity among all the LEDs tested. Although there was a decrease in intensity in the sixth trial (114 lux), overall, the Blue LED remained the brightest and showed a large variation among measurements.

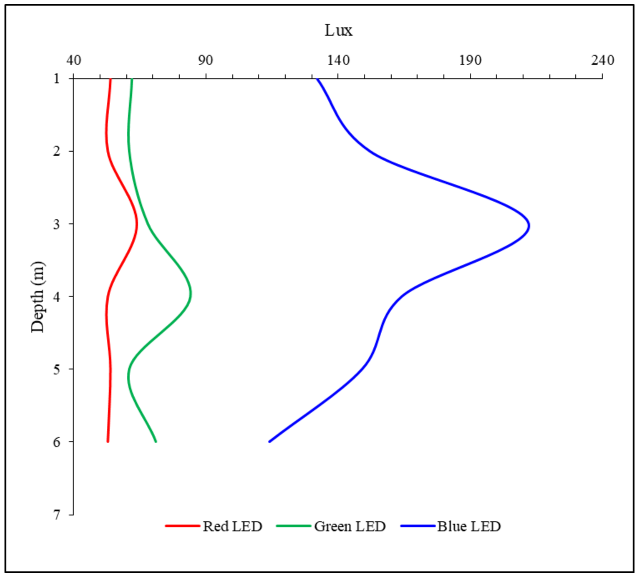

Fig. 2. Graph of LED-RGB lamp lux

2. Observation results of fish behavior under the lights

Observations of fish attraction to light from RGB (red, green, blue) lamps showed significant differences in fish distribution at various depths and observation times (Fig. 3). Each color of light influenced the schooling patterns of fish and the movement of large fish differently, which can be further explained based on the results obtained.

The results of measuring the depth of fish schools at Red LED lamps were relatively low compared to the other two types of lamps (Green and Blue LED), ranging from 1.5 to 3.5 meters. For a duration of 5 and 10 minutes, on average, fish were at a depth of 2 meters. Green LED lamps showed significant variations in terms of the depth of fish schools and duration, where fish were between 4 and 10 meters. Meanwhile, the measurements under Blue LED lamps were generally higher compared to both Red and Green LEDs, with fish schools found between 9 and 12 meters and tending to remain stable over time.

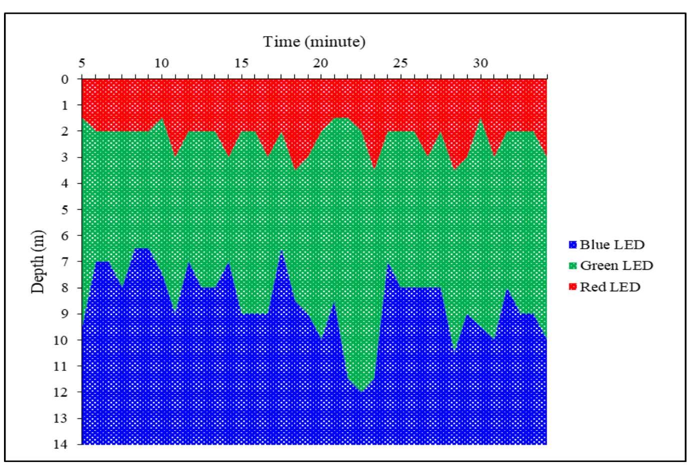

Fig. 3. Fish depth distribution under different LED-RGB lights

3. Proportion of fish catch using LED-RGB lights on FADs

A total of 94 fish were captured across sixth trials using LED-RGB light configurations on fish aggregating devices (FADs). The catch comprised three main species: Indian scad (*Decapterus russelli)*, rainbow runner (*Elagatis bipinnulata*) and bigeye scad (*Selar crumenophthalmus)* (Table 1). The dominant species was Indian scad accounting for 88% of the total catch (83 individuals), followed by rainbow runner (8 individuals, 8%) and bigeye scad (3 individuals, 4%). The catch data indicates that Indian scad exhibited a strong aggregation response to the LED-RGB lighting system with present in all sixth trials. Meanwhile, rainbow scad and bigeye scad were less responsive. Rainbow runner was caught sporadically in three of the sixth trials, while bigeye scad was only present in one trial, contributing minimally to the total catch. This suggests a species-specific response to the artificial lighting, potentially influenced by their behavioral traits, habitat preferences, or phototactic tendencies.

Table 1. Species composition and proportion of fish catch using LED-RGB lights on Fish Aggregating Devices (FADs) in Ternate across sixth trials

Species	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Total Catch	Percentage (%)
Indian scad *(Decapterus russelli*)	8	14	13	13	23	12	83	88
Bigeye scad *(Selar crumenophthalmus)*	3	0	0	0	0	0	3	4
Rainbow runner *(Elagatis bipinnulata)*	3	4	0	0	1	0	8	8
Total Catch	14	18	13	13	24	12	94	100

DISCUSSION

This study investigates the effectiveness of LED-RGB lights on fish aggregating devices (FADs) into gill net fishing operations and their effectiveness in improving catch efficiency by leveraging fish behavioral responses to specific light wavelengths. The application of RGB lighting in fishing gear demonstrates significant potential to optimize fishing strategies by attracting fish from various depths based on the spectral properties of each color. Light color and intensity are known to influence fish behavior, as certain wavelengths can effectively attract fish depending on their habitat depth and visual sensitivity **(Choi *et al*., 2009; Guntur *et al*., 2015; Nguyen & Winger, 2019)**.

Blue light, characterized by its short wavelength and high penetration capacity, can reach deeper water layers, making it suitable for attracting fish inhabiting lower depths **(Patty, 2010; Yulianto *et al*., 2014)**. Green light, which penetrates moderately and has a medium spectral range, is effective for attracting fish at mid-depths and plays a role in maintaining fish aggregation around the illuminated area **(Marchesan *et al*., 2009; Susanto *et al*., 2018; Lin *et al*., 2019; Yu *et al*., 2022)**. Red light, having the longest wavelength and lowest penetration, is primarily effective in shallower waters **(Huang *et al*., 2021; Zulkarnain *et al*., 2023)**. The lighting strategy used in this study involved the sequential activation of blue, green, and red LEDs to target fish at progressively shallower depths—initially attracting fish from deep waters with blue light, then concentrating them at mid-depths with green light, and finally drawing them closer to the surface using red light.

Field observations across six trials confirmed depth-specific responses to the different light colors: blue light attracted fish at depths of 4–6 meters, green light extended the concentration to 4–8 meters, and red light increased fish presence in surface waters. These behavioral responses suggest that the sequential use of RGB lights can effectively manipulate vertical fish distribution, thereby enhancing capture efficiency. Moreover, the use of RGB LEDs offers strategic advantages over conventional white lights. While white lights emit a broad spectrum that may attract a wide range of species indiscriminately, potentially disrupting natural behavior and increasing bycatch. RGB lights can be selectively operated to attract target species at specific depths, thereby reducing ecological disturbances and improving selectivity. This flexibility supports a more sustainable approach to fishing by minimizing pressure on non-target species and sensitive habitats **(Kakai, 2019; Post *et al*., 2024)**.

Catch composition analysis further revealed a dominance of Indian scad in the total catch, suggesting a species-specific attraction to the RGB light configuration. Indian scad are known to form large surface schools and are highly sensitive to light, especially conditions that mimic natural moonlight **(Sudirman *et al*., 2020)**. In contrast, species like bigeye scad and rainbow runner, which generally inhabit deeper waters or are less responsive to surface light cues, were caught in lower numbers. These results highlight the potential for RGB lighting to enhance catch efficiency while maintaining ecological selectivity. However, the study's findings are limited by its short duration (June–August 2024) and localized setting, which may not fully capture seasonal variations or broader ecosystem dynamics. Future studies should expand to multiple seasons and geographic locations to validate these outcomes and refine light-based fishing strategies.

In conclusion, the results of this study indicate that RGB LED lighting systems, when used strategically, can enhance the selectivity and efficiency of gill net fishing. This method offers a promising approach for improving fisheries productivity while supporting more sustainable and environmentally responsible fishing practices.

CONCLUSION

This study highlights the significant potential of LED-RGB lights in enhancing the efficiency of fish aggregating devices (FADs) in Ternate waters. The experimental results demonstrated that different light colors (red, green, and blue) influence fish aggregation at varying depths, with blue LEDs attracting fish to deeper waters (9–12m), green LEDs concentrating fish at mid-depths (4–10m), and red LEDs being most effective in shallow waters (1.5–3.5m). The dominance of indian scad (*Decapterus russelli*) in the catch composition suggests a strong phototactic response to LED-RGB illumination, while other species such as bigeye scad (*Selar crumenophthalmus*) and rainbow runner (*Elagatis bipinnulata*) showed lower attraction rates.

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