Design of remote-controlled Underwater Fish Attractor Light (UFAL) for gillnets

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Abstract. An Underwater Fish Attractor Light (UFAL) is a device used to attract fish in aquatic environments, especially during the night. It emits light to draw fish toward the area, enhancing the chances of successful fishing. This study aimed to design, develop, and evaluate the effectiveness of a remotely controlled UFAL, specifically tailored for gill net fishing. The UFAL was designed to improve fish capture efficiency, enhance energy consumption using chip-on-board LED technology, and ensure durability in aquatic environments. The system, equipped with a fish finder for remote operation and control, was tested for light distribution, battery efficiency, water resistance, and its impact on fish catch rates. Results demonstrated a 189% increase in total fish catch weight when using UFAL, with a total of 281.54 kg compared to 149.12 kg without it. The UFAL maintained a light intensity of 133 lux at 90° and 270° at the start, which decreased to 60 lux after 60 minutes. Battery efficiency allowed extended operation, with a voltage drop to 9.28 V at full brightness after 120 minutes. Additionally, the most effective leakage treatment achieved 0% leakage, ensuring durability.

1 Introduction

The capture fisheries sector in Indonesia has made a significant contribution to food provision and economic resources. Capture fisheries represent a vital economic sector in Indonesia, providing income and livelihoods for coastal populations. One commonly used method of fish capture is the use of gill nets, which passively capture fish by leveraging their swimming behavior through the net.

In an effort to enhance the efficiency of fish capture using gill nets, extensive research has been conducted to identify innovative methods. One intriguing innovation involves the use of underwater lights as fish-catching aids [1]. Underwater light can attract fish to gill

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nets, increasing the chances of successful capture [2]. Further add that when light is emitted underwater, it initiates a food chain interaction process where zooplankton congregating around the light attract predators, ranging from the smallest to larger ones.

The use of underwater lights in the context of gill nets presents its own challenges. Gill nets are typically employed in passive fishing modes and require appropriate light to attract fish swimming horizontally. Therefore, the development of a remote-controlled underwater fish attractor light (UFAL) is needed, capable of providing effective illumination to attract fish swimming parallel to the gill nets. The use of artificial underwater lighting is relatively limited. Previous research in this area, in addition to aiding fish with negative phototaxis in their search for food, also holds promise for reducing ecosystem damage caused by fishing equipment [2].

The use of underwater submersible lights has a positive impact on capture fisheries, leading to increased catch rates. The catch results obtained from fishing with gillnets using lights surpass those without lights [3]. Further notes that despite the advantages of using illuminated fishing gear, there are still some drawbacks, such as rapid battery depletion and unstable light output as the battery power diminishes [3].

Efficiency in power usage and optimal light distribution can be achieved through a remote control system using batteries within the lamps and light adjustment using a dimmer. The incorporation of batteries in the lamps helps reduce operational costs and enhances fish capture efficiency [3]. Adjusting the light intensity can conserve power consumption and mitigate the operational expenses of fishing [4].

This research aims to design and develop a prototype of remote-operated UFAL specifically designed to enhance the efficiency of fish capture with gill nets. The utilization of state-of-the-art technology, such as chip-on-board (COB) LED, is expected to enhance the device's effectiveness in attracting target fish and making a positive contribution to the overall fisheries industry [4]. The use of light manipulation in fish capture is also expected to enhance catch yields by manipulating biological rhythms using artificial light. The utilization of UFAL technology featuring COB LED represents an innovative step towards improving fish catch outcomes in a more efficient, effective, and sustainable manner, making a significant contribution to the overall fisheries industry.

2 Materials and method

2.1 Description of the study sites

Research activities consisted of laboratory based, swimming pool, and field based activities. Laboratory-based activities were conducted in campus for distribution of light generated by UFAL, and battery usage. The swimming pools nearby campus for leakage test. Field-based activities were conducted in Madura strait, a coastal waters of Pasuruan, East Java Province (Figure 1) for UFAL testing to determine its effectiveness from volume of captured and species composition.

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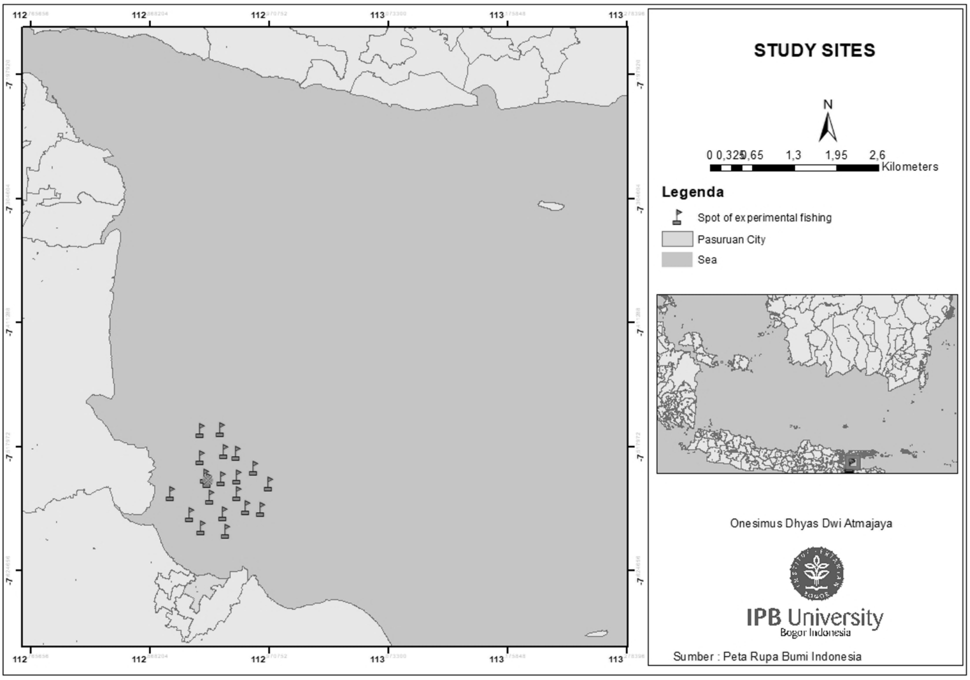


Fig. 1. The location of Madura Strait, East Java, Indonesia.

2.2 Materials

Materials to build a unit of UFAL consisted of four units of chip-on-board LED of 75 W, one unit of dry battery of 12 volts - 5 Ah [13], one transparent acrylic tube 15 cm height and 12 cm diameter [4], one PVC Tube Cap [6] and four channel NYM wire of 3 meters. The study uses radio control and transmitter to adjust the brightness of the light [7]. A lux meter for determining light distribution in laboratory, a voltmeter for determining battery usage, smartphone for application of location locator, counting the number of fish, scale to measure the weight of fish and ropes to hold the UFAL with a length 3 meters.

2.3 Procedure to develop UFAL design

The design concept of the underwater fish attractor lights, known as the Underwater fish attractor light (UFAL), may involve several key components such as lights, acrylic tubes, tube caps, cables, and weights. The stages of the UFAL design concept are illustrated in Figure 2.

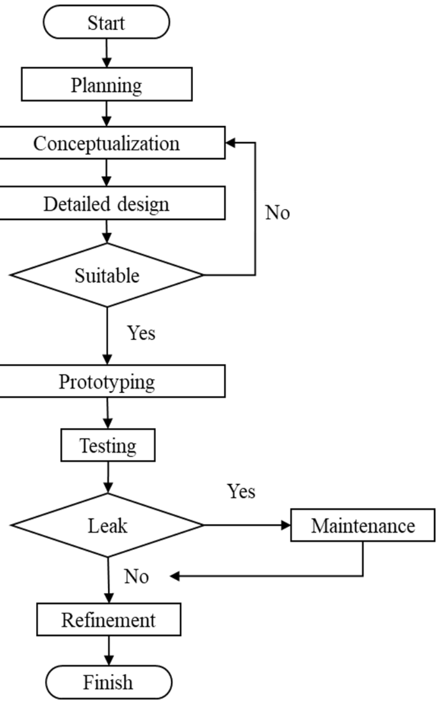


Fig. 2. The stages of the UFAL design concept.

2.4 Light distribution test

Testing the light distribution in the air is a crucial step in the development and evaluation of the UFAL or similar devices. This testing method aims to ensure that the light emitted by the UFAL reaches the desired area and is effective in attracting fish. The light distribution is tested by measuring the light distribution in the air. To analyze the light distribution in the air, a light intensity measurement tool using a lux meter can be used [8]. Measuring the light intensity at various distances from the UFAL is necessary to understand the extent of the reached light. The measurement of light illumination at a specific point can be calculated using the following formula:

$$E = I/r^2 \quad (1)$$

Where:
E = Light Illuminance
I = Light Intensity
r = Distance from the light source

2.5 Battery efficiency test

Testing the efficiency of the batteries in the UFAL is crucial to understanding how long they can power the UFAL, how long they last, and how well they maintain their capacity during use. The analysis of battery efficiency test results provides information about how long the UFAL can operate before the battery is depleted, how efficiently the UFAL consumes power, and how well the battery can maintain its power capacity. These measurements can be used to optimize battery usage, determine the appropriate battery capacity, or select a more efficient battery type if necessary. The battery efficiency formula measures the extent to which the battery can convert chemical energy into electrical energy and is used to operate specific devices. Battery efficiency (η) can be calculated using the following formula:

$$\eta = \frac{EOut}{EIn} x\ 100\% \qquad (2)$$

Where :
η = Battery Efficiency
$EOut$ = Electrical energy output by the battery
EIn = Chemical energy stored in the battery before conversion into electrical energy

2.6 Leakage test

Leakage testing on the UFAL is a crucial step in testing the integrity and water resistance of the UFAL to ensure that the lights and electronic components within the UFAL continue to function effectively in the aquatic environment. Waterproof testing involves three treatments: testing for 2 hours, 4 hours, and 5 hours. Periodic testing aims to evaluate and improve the level of leakage in the lamp tube. Waterproof testing on the UFAL is analyzed descriptively based on field measurements using various waterproofing methods applied to the UFAL tube. Leakage criteria are assessed based on the percentage of leakage level that can be visually observed during leak testing in a swimming pool.

2.7 UFAL effectiveness test

The effectiveness test of the UFAL is a research and testing process designed to assess the extent to which the UFAL can enhance fish catch results in gillnet fishing or other fishing methods. This effectiveness test is essential to ensure that the UFAL fulfills its purpose as a fish attracting device and improves catch results. The testing was conducted using two units of gillnet fishing boats. Two fishing boats operated simultaneously separated by approximately 1 km, two sets of gillnets of same specification: mesh size of 2 inches, net length of 50 meters per piece, 1 m below sea surface, net height of 1.5 m. Each boat made 20 night-fishing trips from March 7 – April 14, 2024, once setting from 07.00 PM to 10.00 PM. UFAL was placed between 6th and 7th net pieces, 2 metres below sea surface. The operation of the gillnet fishing gear using the lights is visualized in Figure 3.

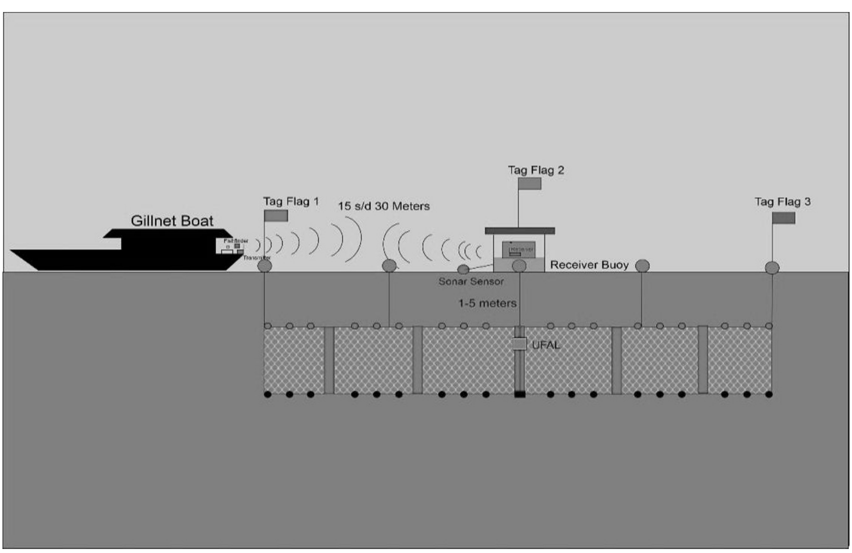


Fig. 3. Placement of UFAL on a gillnet.

The gillnet with a lamp is operated using a dimmer and a fishfinder. The dimmer settings based on fishfinder parameters are explained in Table 1.

Table 1. The dimmer settings based on fishfinder parameters

No.	Treatment	Number of Fish Gathered (Sonar)	Brightness Level
1	Setting	Few	25%
2	Attracting	Many	100%
3	Concentration	Normal (trapped)	50%
4	Hauling	Normal (trapped)	10-0%

The testing of the underwater fish attractor light's effectiveness is analyzed descriptively based on the testing formula as follows:

$$E = \frac{C_{UFAL}}{C} x\ 100\% \qquad (3)$$

Where:

E = The effectiveness of UFAL (%)

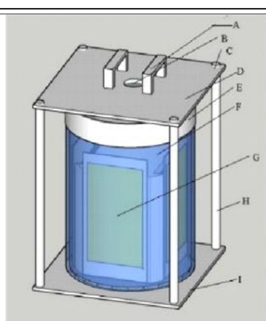
C_{UFAL} = Fish caught by gillnets using UFAL (weight or number of fish)

C = Fish captured by gillnets without UFAL (weight or number of fish).

3 Results and discussions

3.1 The UFAL

The design of the underwater fish attractor light (UFAL) is meticulously engineered to seamlessly integrate with gillnet fishing gear, exemplifying a user-centric approach that prioritizes simplicity and practicality. This design facilitates effortless attachment, disassembly, and reattachment of the UFAL to the gillnet equipment, ensuring that fishermen can readily incorporate this technology into their existing setups without necessitating intricate modifications. Such a user-friendly design enhances accessibility across a diverse range of fishermen, irrespective of their technical proficiency, thereby reducing adoption barriers. Additionally, the UFAL's versatility, stemming from its ability to be affixed or removed as needed, offers fishermen the strategic advantage of deploying it selectively based on their operational objectives and the behavioral characteristics of the target fish species. This adaptability amplifies its efficacy in attracting fish, thereby augmenting the overall efficiency of the fishing process. The results of UFAL design can be seen in Figure 4.



Point	Description
A	Handle lamp
B	Cable channel hole
C	Threaded iron frame
D	Upper frame base
E	Lamp cover tube cap
F	Lamp battery
G	Lamp chips
H	Lamp support frame
I	Lower frame base

Fig. 4. Result of UFAL design

After obtaining the design, the assembly of the lamp circuit was carried out according to the materials described in Table 1. The prototype of the underwater fish attractor light has been assembled according to the designed configuration, as shown in Figure 5.

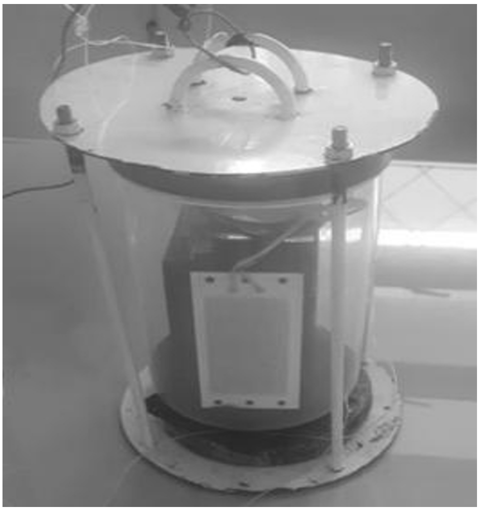


Fig. 5. Prototype of UFAL

Following the meticulous assembly of the prototype, it undergoes a comprehensive testing phase to assess its performance across multiple critical parameters. The evaluation encompasses an intricate analysis of light distribution, battery efficiency, water resistance, and its effectiveness in fish capture. The assessment of light distribution seeks to ensure that the emitted light effectively reaches the desired underwater area, thereby maximizing its capacity to attract fish [3]. Battery efficiency analysis is imperative to gauge the prototype's ability to utilize power resourcefully, offering insights into its operational longevity and energy consumption patterns [9].

The waterproof testing is crucial in validating the UFAL's durability and functionality in aquatic environments, guaranteeing that it can endure prolonged submersion without compromising its performance. Subsequently, the evaluation of its effectiveness in capturing fish elucidates the extent to which the UFAL fulfills its primary purpose as a fish-attracting device, thereby determining its potential utility in enhancing catch yields [10]. This multifaceted testing regimen ensures that the UFAL prototype not only meets but also excels in critical performance benchmarks, positioning it as a robust and effective tool for fisheries enhancement. The results of the light distribution testing in the air for the underwater fish attractor light, tested using a 12 Volt 5 Ampere battery, can be seen in Figure 6.

3.2 Light distribution

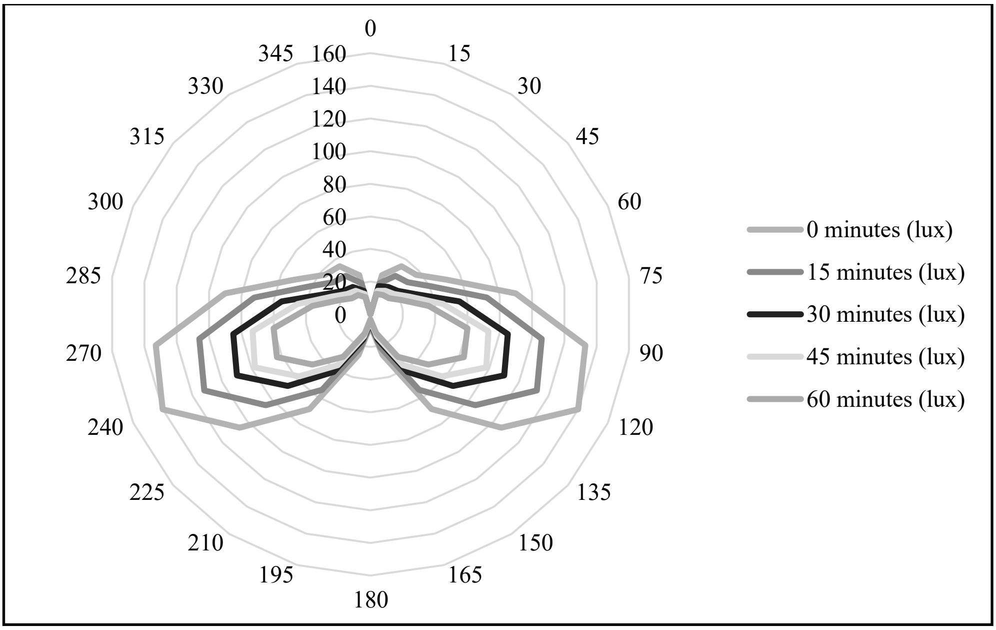


Fig. 6. Light Distribution of the Underwater Fish Attractor Light

The measurement results of light intensity show a gradual decrease minute by minute at various angles. At minute 0, the highest intensity was recorded at 90° and 270° angles (133 lux), while the 180° angle had the lowest intensity (7 lux). After 15 minutes, the intensity at 90° and 270° angles decreased to 106 lux, with a similar downward trend at other angles. At 30 minutes, the intensity at 90° and 270° angles further dropped to 85 lux, while the 180° angle was only 5 lux. At minute 60, the intensity at all angles reached the lowest values, with 90° and 270° angles at 60 lux, and the 180° angle at just 3 lux. The data indicates that the UFAL maintains strong performance for the first 30 minutes. Beyond this point, light output decreases more rapidly, particularly at certain angles.

3.3 Battery efficiency

Continuous evaluation over an extended period should be conducted to ensure the battery's capacity remains sufficient for the LED lamps. These insights are critical for understanding the battery performance and operational limits of the UFAL. The battery usage for UFAL is elucidated in Figure 7.

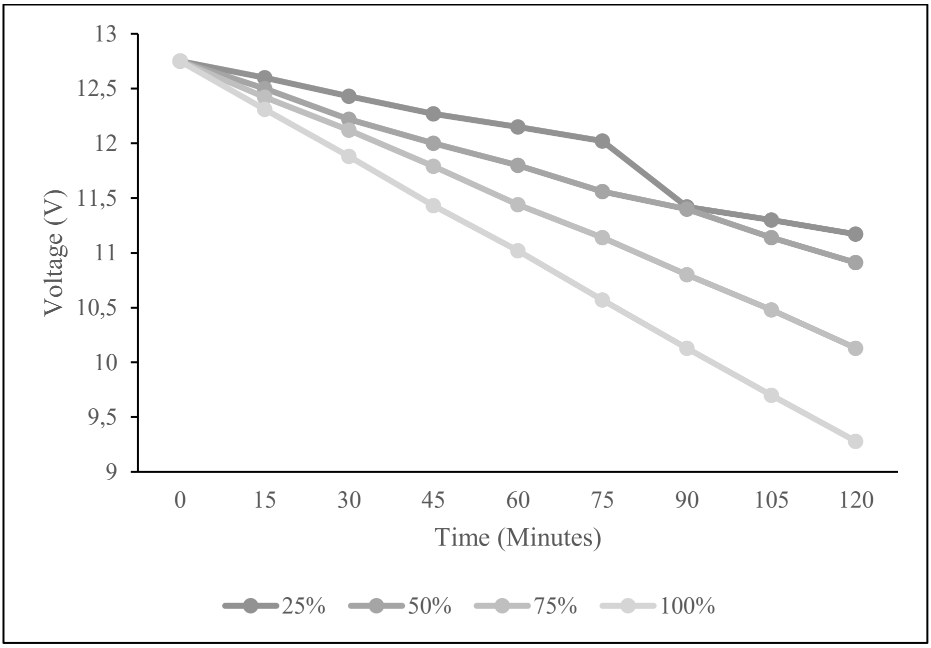


Fig. 7. Battery Utilization for the UFAL

Figure provides an analysis of the voltage behavior of a 12V 5Ah battery measured over a 2-hour period at four brightness levels: 25%, 50%, 75%, and 100%. Initially, the battery voltage is stable at 12.75V across all brightness levels, indicating a full charge. Over time, the voltage begins to decrease, with higher brightness levels causing faster depletion. After 60 minutes, the voltage at 100% brightness drops to 11.02V, while it remains at 12.15V at 25% brightness. By 120 minutes, the voltage at 100% brightness falls significantly to 9.28V, compared to 11.17V at 25%. This shows that operating at full brightness drains the battery more rapidly, whereas lower brightness levels extend battery life. The data indicates a clear relationship between brightness and battery depletion, with higher energy consumption leading to faster voltage drops.

Managing brightness levels effectively can prolong the battery's operational time, which is crucial for devices like the UFAL that require sustained illumination. Effective battery management [11], is critical for optimizing battery performance, ensuring longer-lasting power and more efficient energy use in practical applications. These findings suggest the importance of balancing brightness and energy usage to optimize battery performance over time. After conducting the light distribution and power consumption tests, a water resistance test was performed, the results of which are presented in Table 2.

3.4 Leakage test

Leakage testing is conducted to assess the device's resistance to water and ensure that the equipment, such as the UFAL (Underwater Fish Attractor Light), does not experience leakage or damage when submerged. The test is essential to ensure the device functions in water and is durable enough for long-term use without losing performance. The results are presented in Table 2.

Table 2. Results of Waterproof Testing on UFAL Housing

Repair Treatment	Water Entered (ml)	Soaking Time (hours)	Leak Percentage (%)
No Addition	500	2	50 %
Thread Repair	210	2	21 %
Addition of Silicone Glue	98	1	9.8
Silicone & Hot Glue	32	1	3.2
Addition of Double Tube	9	1	0.9
Double Tube & Hot Glue	0	1	0

The table illustrates the effectiveness of various repair treatments in reducing water leakage in a 1-liter capacity tube. The highest leakage occurred without any treatment, with 50% of the water leaking in 2 hours, while the "Thread Repair" and "Silicone Glue" treatments reduced leakage to 21% and 9.8%, respectively. The combination of "Silicone & Hot Glue" showed further improvement, with only 3.2% leakage. Combining sealants, like silicone and hot glue, enhances durability due to their flexibility and water resistance. Additionally, the "Double Tube" method reduced leakage to just 0.9%, and the combination of "Double Tube & Hot Glue" achieved a complete seal with 0% leakage. This supports [12] conclusions that combining structural reinforcements with adhesives optimizes sealant performance. Overall, the table's results highlight that employing multiple methods, both adhesive and structural, significantly improves water retention and leak prevention. After the underwater attractor light had been tested in the laboratory and was ready, the next step was to test the effectiveness of using the submersible light on the Gillnet fishing gear in the Madura Strait, Pasuruan City, East Java, Indonesia.

3.5 UFAL effectiveness

The capture results of the Gillnet treatment using the light and the capture results without the light in number are shown in Figure 8 and Figure 9 in weight (grams).

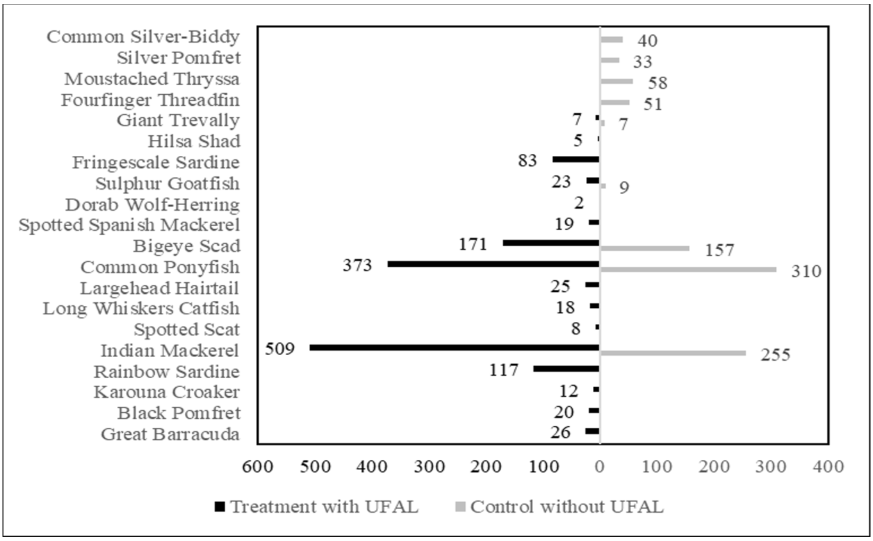


Fig. 8. Catch results of Gillnet fishing gear with UFAL and without UFAL in number.

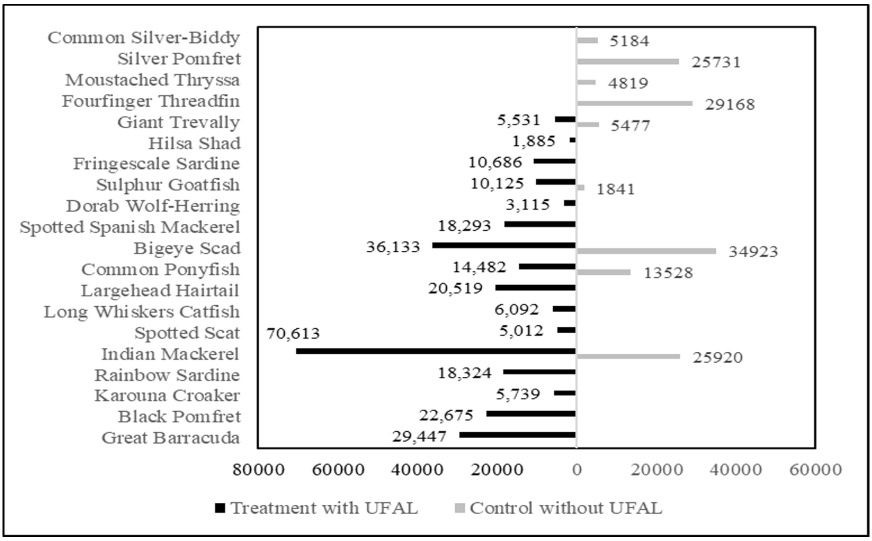


Fig. 9. Catch results of Gillnet fishing gear with UFAL and without UFAL in weight (grams).

Gill net catches showed significant differences between the use of underwater fishing attractor lights (UFAL) and without UFAL. With UFAL, Indian Mackerel (*Rastrelliger kanagurta*) became the most dominant species, reaching 509 individuals and 70,613 grams, comprising 35.9% of the total catch. Common Ponyfish (*Leiognathus equula*) also showed an increase, with 373 individuals and 14,482 grams (26.3%). Bigeye Scad (*Selar crumenophthalmus*) was caught in quantities of 171 individuals and 36,133 grams (12.1%), while Great Barracuda (*Sphyraena barracuda*) yielded 29,447 grams. On the other hand, major fish such as Karouna Croaker (*Johnius carouna*) amounted to 5,739 grams, and Rainbow Sardine (*Dusumeiria acuta*) reached 18,324 grams.

Without UFAL, Indian Mackerel remained the most caught fish with 255 individuals and 25,920 grams, followed by Common Ponyfish with 310 individuals and 13,528 grams. Fish behavior toward light varied according to species and habitat. Indian Mackerel (*Rastrelliger kanagurta*) is a pelagic fish highly attracted to light as it follows plankton aggregating around the light source. Common Ponyfish (*Leiognathus equula*) and Bigeye Scad (*Selar crumenophthalmus*) also exhibit similar behavior, often being attracted to light while foraging [13]. Rainbow Sardine (*Dusumeiria acuta*) tends to gather near the water surface when attracted to light. However, some fish like Fourfinger Threadfin (*Eleutheronema tetradactylum*) and Moustached Thryssa (*Thryssa mystax*) are not attracted to light and prefer to stay near the sea bottom [14]. Thus, fish behavior patterns toward light are highly dependent on their feeding habits and natural habitat. Overall, the total catch was 1,418 individuals, weighing 278,671 grams with the UFAL treatment, and 920 individuals, weighing 146,591 grams without UFAL. The total catch by weight with the gillnet using UFAL was 189% higher than without UFAL. Fishing can be considered effective when the catch effectiveness rate is above 50% [15].

4 Conclusions

The research yielded several important results. First, the design of the Underwater Fish Attractor Light (UFAL) was optimized for gillnet integration, allowing for easy attachment and detachment while maintaining user-friendliness. In terms of light distribution, the UFAL demonstrated consistent illumination, with light intensity gradually decreasing over time but maintaining sufficient brightness for the first 30 minutes of operation. Battery usage tests revealed that while higher brightness levels depleted the battery more quickly, effective battery management could extend operational time, showing a relationship between brightness settings and energy consumption. Leakage treatment tests highlighted the success of combining structural reinforcements and adhesives, with the most effective treatment achieving 0% leakage using a double tube and hot glue method. Finally, field tests showed that UFAL significantly improved catch rates, with an increase of 189% in fish catch weight, demonstrating its effectiveness in attracting target fish species and enhancing overall fishing efficiency.

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