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The Effectiveness and Distribution of Fishing Light Attractors on the Stationary Lift Net

Fuad Fuad[1*], Mimit Primyastanto[1], Doddy Pranowo[2], Eka Maulana[3] , Wahida Kartika Sari[1], Supriyadi Supriyadi[4]

[1]Faculty of Fisheries and Marine Science, University of Brawijaya, Indonesia
[2]Faculty of Agricultural Technology, University of Brawijaya, Indonesia
[3]Faculty of Engineering, University of Brawijaya, Indonesia
[4]Faculty of Fisheries Socio-Economic, PSDKU Kediri, University of Brawijaya, Indonesia

E-mail Address : fuad@ub.ac.id

KEYWORDS

catchable area;
effectiveness;
pelagic fish;
light-emitting diode.

Abstract A stationary lift net requires an effective fishing light attractor. The intensity and distribution of light are important factors to increase the effectiveness of fishing light attractors. This study aimed to probe the distribution of light intensity and its effect on the effectiveness of fishing light attractors. This research employed a descriptive-comparative method by comparing the effectiveness of LED lights with kerosene lights. The results showed that the concentration of fish school in LED lights was at a depth of 4–10 m with a light intensity of $1x10^{-8}$– $10x10^{-8}$ W/cm^2, while the kerosene lights was deeper than LED lights at a depth of 8–12 meters with a light intensity of $1x10^{-8}$– $10x10^{-8}$ W/cm^2. The distribution of fish schools from LED lights tends to be concentrated and form larger schools than kerosene lights. The optimum light intensity of LED and kerosene lights was almost the same, in the range of $1x10^{-8}$– $10x10^{-8}$ W/cm^2, with concentrations of fish schools reaching 65% and 64%, respectively. The total catch of LED lights fish during eight fishing trips was 168.5 kg or an average of 21.06±2.32 kg/trip, while the total catch of kerosene lights was 139.6 or an average of 17.5±1.98 kg/trip.

Introduction

Fisherman use lights to increase catches has been done for hundreds of years (Nguyen *et al.*, 2021). Lighting technology continues to be used today by purse seine, lift net, and gillnet fisherman. Light fishing provides many advantages and is the most effective method for catching squid, anchovies, yellow-striped scads, mackerel fish, and mackerel scads (Yamashita *et al.*, 2012; Taufiq *et al.*, 2016; Fuad *et al.*, 2019; Susanto *et al.*, 2017a). Fisherman widely use one type of lamps: kerosene lights, fluorescent, and Light-Emitting Diode (LED). Stationary lift net fisherman widely use these three types of lights to lure fish (Guntur *et al.*, 2016).

Stationary lift net fisherman use kerosene lights and LED lights as fishing aids. Those lamps aids play an essential role in attracting fish to gather in the catchable area (Fuad *et al.*, 2016; Rudin *et al.*, 2017). After the fish gather in the catchable area, fish trapping is carried out. The lights in a stationary lift net are operated in two ways, on water and underwater (Kumajas, 2015; Sulkhani *et al.*, 2014). The lights that operate underwater have a more complicated design, but the intensity of the light spreads evenly. Meanwhile, lamps operated on the water are simpler, but the water's surface primarily reflects the intensity of the light. Much research on the operation of lamps using the two methods above has been

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carried out. Fuad *et al*., 2019 reported that lights operated underwater were more effective at attracting fish than lights operated above water. Lamps underwater produce brighter light and less electrical power (Sakri & Hajisamae, 1999; Nguyen & Winger, 2019).

LED lights are one type of lamps that is effective in collecting fish and efficient in electric power. The electric power consumption of LED lights is more efficient than mercury (CFL) (Susanto *et al*., 2015; Cahyadi & Xing You., 2016). Research on the effectiveness of LED lights is often carried out on the topic of light color (Fuad *et al*., 2019; Cahyadi & Xing You, 2016), light intensity (Baskoro *et al*., 2002; Guntur *et al*., 2016), and electric power efficiency (Nguyen *et al*., 2021; Yamashita *et al*., 2012; Taufiq *et al*., 2016; Ramadhan *et al*., 2016). The effectiveness of LED lights on the number and types of fish varies greatly. For example, LED lights on a stationary lift net are very effective at attracting anchovies, and the catch is almost the same as traditional lights (Susanto *et al*., 2017b). The performance of LED lights is lower than that of metal halide lamps in squid fishing with fishing rods. Differences in effectiveness and performance occur due to differences in light characteristics, such as light distribution, intensity, distribution of fish behavior (Yamashita *et al*., 2012; Matsushita *et al*., 2012; Fuad *et al*., 2019). Based on the description above, it is imperative to probe the characteristics of light distribution, light intensity, and fish distribution around the light.

Furthermore, there is still a dearth of research on the characteristics of the distribution of light intensity and its effect on the effectiveness of lamps performance. The distribution of light intensity is the amount of light energy at each point in the waters. The distribution of light intensity affects the preferences and speed of fish forming schools. The level of preference and the speed at which fish form a school significantly affect the effectiveness of the lamp's performance. Based on the distribution of light intensity characteristics above, this study aimed to investigate light intensity distribution and its effect on the fishing light attractors' effectiveness.

Materials and Methods

The research was conducted at the fisheries and marine resource exploitation laboratory and Pasuruan Sea in October to November 2021. The equipment used for the research was an echosounder, international light technology, stationary lift net, and fishing light attractors. Measurement of the distribution of light intensity used ILT 5000 while monitoring the distribution of fish used an echosounder. Lights were used as a tool to lure fish so that fish gather in a catchable area. Kerosene lights were used as a control (baseline) on the performance of underwater LED lights. Fish distribution data on LED and kerosene lights were carried out during the setting. The average setup time ranged from 3 to 3.5 hours. Observation time was divided into several intervals to produce more detailed data. Each observation interval lasted ten minutes. Fish distribution data storage was conducted in the last 2 minutes in each observation interval. In one fishing trial, there were 18 observation intervals. The observation results of fish distribution were stored in the echosounder memory. The observation time interval was applied to all lamps trial.

The light distribution analysis was aimed to determine the range of light intensity in all catchable areas of the stationary lift net. The light intensity unit used was W/cm^2. The light intensity data were averaged according to each measurement point's x, y, and z axes. The x-axis shows the width of the chart, the y-axis shows the depth of the chart, and the z-axis shows the light intensity value at each measurement

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point. Furthermore, the light intensity data was transferred to an excel sheet on the surfer software. Data was stored in the form of extension data. The saved light intensity data was opened in a new sheet and displayed in a grid, and it was arranged based on geometric lines. Furthermore, the data grid was arranged with the kriging method. The gridded geometry data was displayed in the plot column. The display of the light distribution geometry in the plot column was colored according to the desired light contour. The color of the light contour shows the values of the different light intensity ranges, which can be adjusted according to the needs (level of accuracy). The value of the intensity range is different for each color of the lamplight. Each light intensity range has a value between 1-10x10^{-x}.

The fish distribution and light distribution image data were analyzed using Surfer 13 and Photoshop. Before analysis, the fish distribution image data was checked and separated between schools of fish by echo (noise). The echo (noise) in the fish distribution data was removed/deleted to interfere with the validity of the data. The fish distribution image validated was then converted into a transparent form to be overlaid with the distribution of LED lights. Fish distribution image analysis was used to determine the number and position of fish schools at each observation time (McInnes *et al*., 2015; Riyanto *et al*., 2019). Fish distribution image analysis began by overlaying the light scatter image with the fish distribution. The image overlay results produced a composite image that showed the position of the fish school and the light intensity based on depth (Figure 1). The overlayed image is used to calculate the area of the fish school formed around the lamps. The area of the fish school was used as the basis for determining the proportion of fish distribution. The proportion of fish distribution was grouped based on the depth and intensity of the light.

The percentages of vertical fish schools were grouped based on light intensity are 1x10^{-7}-10x10^{-7} W/cm^2, 1x10^{-8}-10x10^{-8} W/cm^2, 1x10^{-9}-10x10^{-9} W/cm^2, and 1x10-10-10x10-10 W/cm^2. Percentage determination of f fish schools based on light intensity refers to Susanto (2017b):

$$P = \frac{pi}{pt}\ x\ 100\%$$

with:
P : Percentage of fish school
pi : Area of fish school at i-interval
pt : Total area of the fish school.

Results and Discussion

Results

The distributions of LED light in the air spread optimally to the side (horizontally), while the vertical light distribution (top and bottom) was less optimal. The highest light intensity was at an angle of 120° and 240° were 2.5x10^{-2} W/cm^2. The lowest light intensity is at an angle of 180 and 360 were 1.52x10^{-3} W/cm^2 (Figure 2a). The vertical light intensity distribution of LED lights in the water only reached a depth of 11 m. The distribution of LED light reached a depth of 11 m with an intensity of 8.64x10^{-10} W/cm^2. The decrease in vertical light intensity of LED lights was more regulated than that of kerosene lights.

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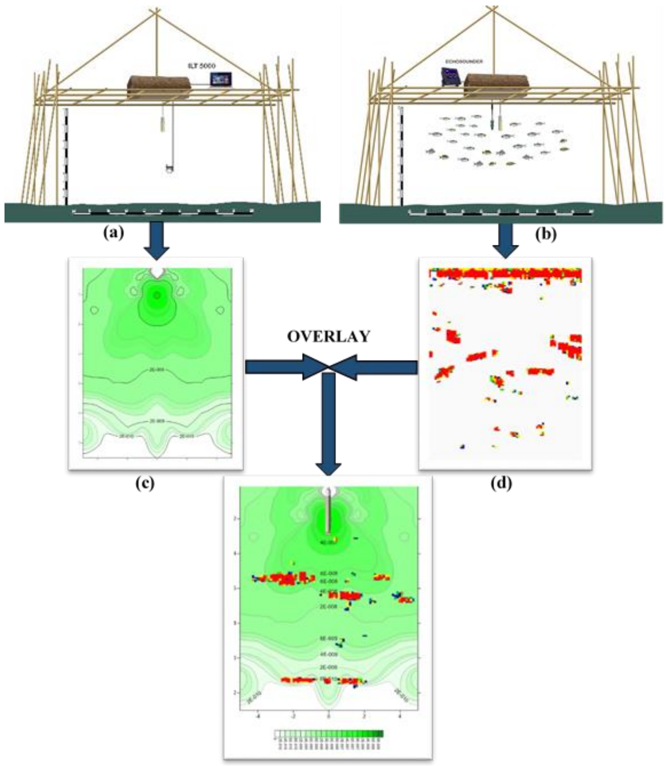
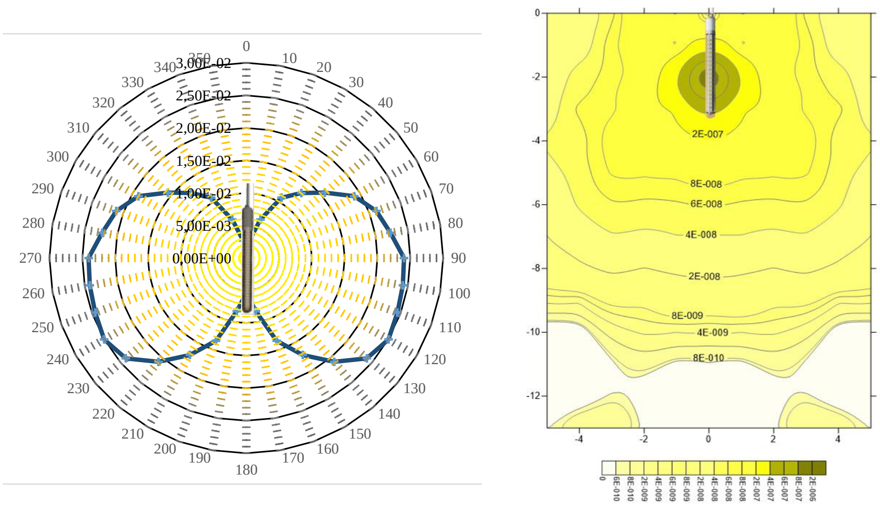


Figure 1. Analysis of overlay data on light intensity and distribution of fish. (a) collecting light distribution data. (b) collecting data on fish distribution. (c) lights distribution data. (d) fish distribution data. (e) result of overlaying light distribution with fish distribution



(a) (b)

Figure 2 Distribution of LED light intensity (a) Distribution of light intensity in the air (b) Distribution of light intensity in the water

The light distributions of the kerosene lights in the air spread sideways and downwards, but it was not optimal in the middle because the body of the kerosene lights blocked the light. The highest light intensity of the kerosene lights was at an angle of 90° and 270° were 9.38 x10^{-5} W/cm^2. The lowest light intensity was at an angle of 180°, which was 3.62 x10^{-6} W/cm^2 (Figure 3a). The light

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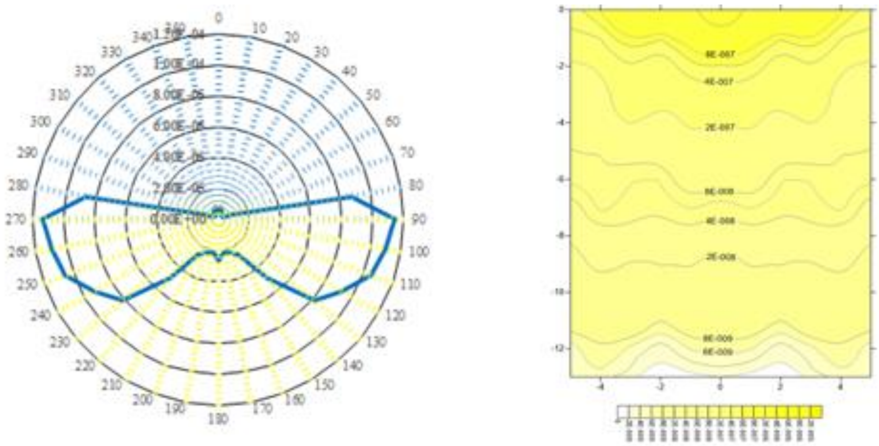
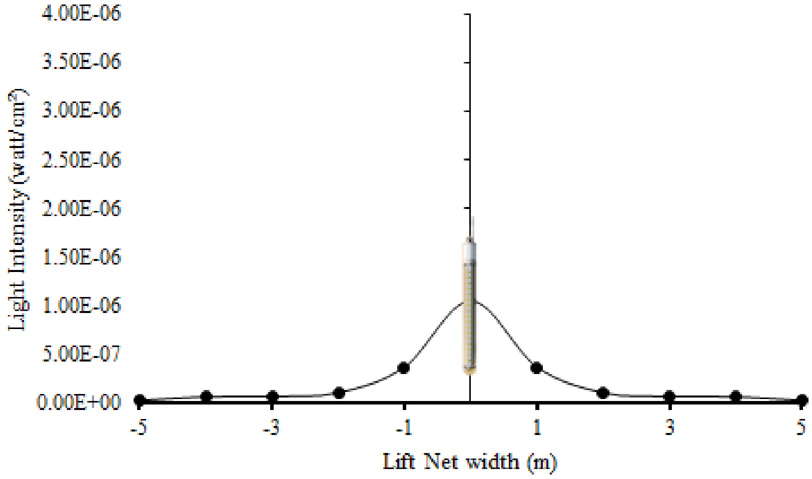
distribution from a kerosene light on the water was almost the same as in the air. The light intensity of the kerosene lights spreads maximally sideways and downwards. The light distribution of the kerosene lights in the water reached a depth of 12m with an intensity of 7.92 x10^{-10} W/cm^2.



(a) (b)

Figure 3 Light intensity distribution of kerosene lights (a) Distribution of light intensity in the air (b) Distribution of light intensity on the water

The vertical light intensity distribution of LED lights ranges from 1.65x10^{-8} W/cm^2 to 8.64x10^{-10} W/cm^2, while the kerosene lights were 3.02x10^{-6} W/cm^2 to 7.92x10^{-10} W/cm^2. The distribution of the horizontal light intensity of LED lights was more regulated than that of kerosene lights. The light intensity decreased with increasing distance from the light source. The decrease in light intensity was strongly influenced by seawater particles and light wavelengths (Nguyen *et al*., 2021). The denser the seawater particles, the greater the intensity absorbed (Riyanto *et al*., 2019). The shorter the wavelength of light, the farther the reach of the light (Yamashita *et al*., 2012). The decrease in light intensity from a radius of 0 m to a radius of 5 m ranged from 3.2x10^{-8}–1.5x10^{-8} W/cm^2. The average light intensity of LED lights at a radius of 0 m is 2.03x10^{-7} W/cm^2, while the average light intensity at a radius of 5 m is 2.35x10^{-8} W/cm^2. The distribution of the horizontal light intensity of the LED lights exceeds the width of the stationary lift net, raising the possibility that the fish will be outside it. It can be seen in Figure 4.



(a) LED Lamp

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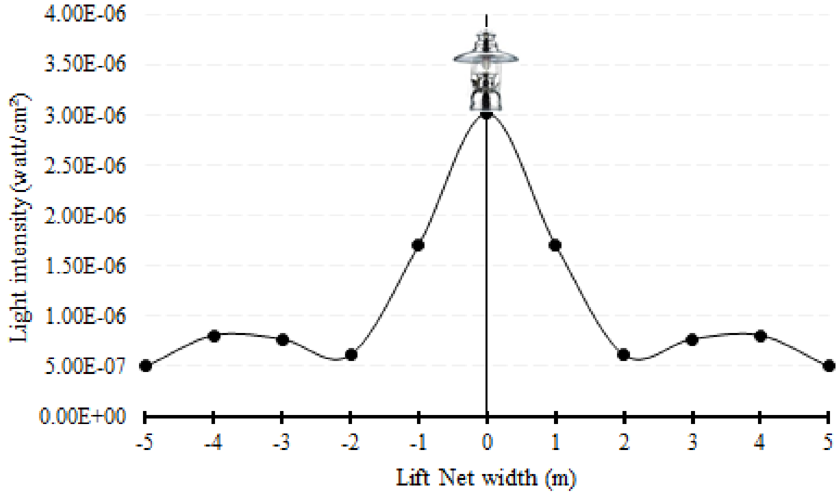

(b) Kerosene Lamp

Figure 4 The average light intensity distribution of the horizontal lamps (a) The light distribution of the LED lights (b) The light distribution of the kerosene lights

The Effectiveness of LED Lights Performance

The effectiveness of lamps performance was measured by the number of coming fish (Nguyen *et al*., 2020), the distribution of fish around the lamps (Fuad *et al*., 2019), and the number of fish caught (Guntur *et al*., 2016). The number and distribution of fish schools around the LED lights were different from the kerosene lights. The schools of fish that come to the LED light were much more and form a more prominent school compared to the kerosene lights. The distribution and percentage of fish schools on LED lights tend to fluctuate. The first fish schools were formed at the second observation interval (the first 20 minutes) at an intensity between $1x10^{-7}$-$10x10^{-7}$ W/cm^2. The fish schools dispersed again at the fourth and fifth observation intervals (40 and 50 minutes). The fish schools were formed relatively stable after an observation interval of six (60 minutes). The schools of fish formed were quite large but small and scattered. The intensity of light strongly influenced the formation of fish schools according to fish preferences (Sulaiman *et al*., 2015). The concentration of fish schools was first formed at a depth of 4-9m or light intensity of $1x10^{-8}$-$10x10^{-8}$ W/cm^2, and the addition of lighting time did not affect the size of the fish schools. The fish school remained scattered, and difficult to concentrate in the lighted area (Figure 5).

Fish schools on LED lights were evenly distributed at a depth of 4-12m or light intensity of $2x10^{-7}$-$6x10^{-10}$ W/cm^2. The highest average percentage of fish schools was found at a depth of 5-8 m or at a light intensity of $1x10^{-8}$ -$10x10^{-8}$ W/cm^2, which was 65%. The percentage of fish schools in this area increased from the first observation interval (5%) to the last observation interval (75%). The highest percentage of fish schools occurred at the eleventh observation interval, which was 82%. The lowest average percentage of fish schools occurred at a depth of 2-5 m or an intensity of $1x10^{-7}$-$10x10^{-7}$ W/cm^2, 9%. Fish schools in this area were volatile. The highest percentage of fish schools in the second observation interval was 95% but decreased to 4% at the last observation interval. The LED light was relatively slow to attract fish coming compared to the kerosene lights. Fish schools formed rather slowly, but there were many of them at the end of the observation interval (Figure 6).

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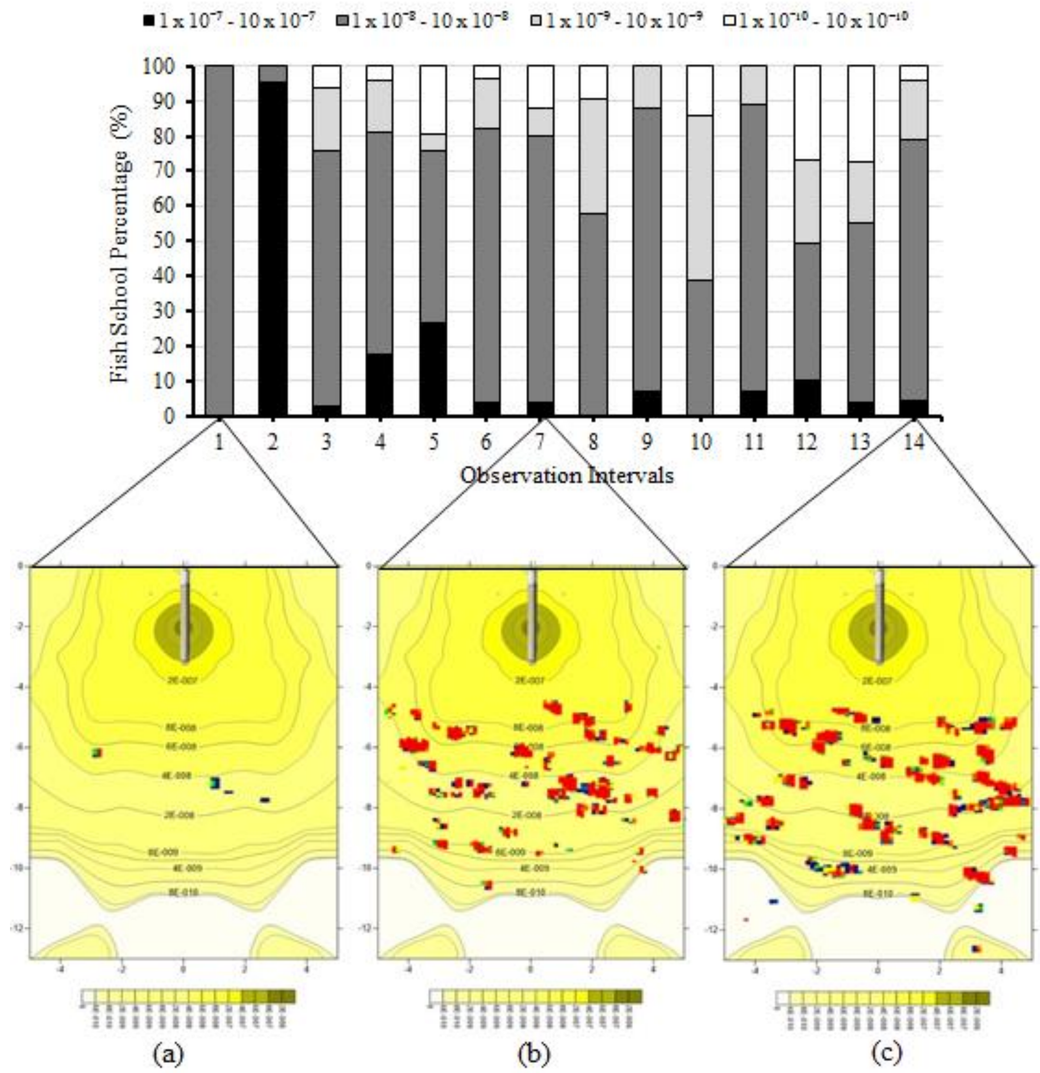

Figure 5 Distribution of fish schools on LED lights (a) First interval (b) Seventh interval (c) Fourteenth interval

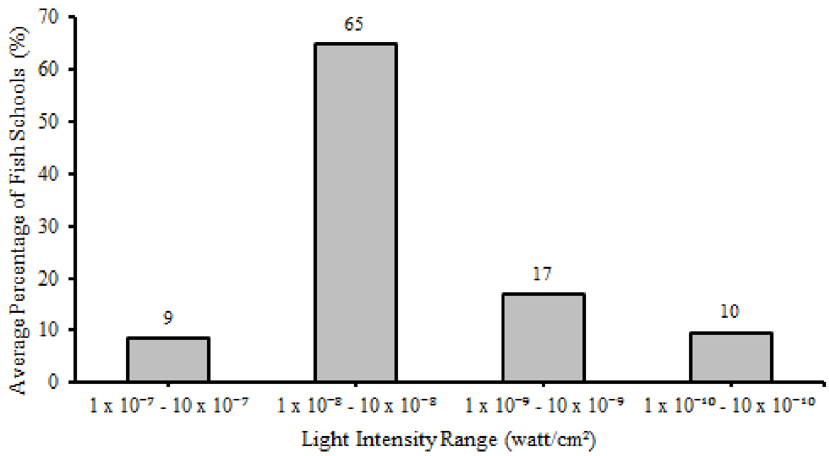

Figure 6 Percentage of fish schools on LED lights

Figure 7 Number and types of fish caught with LED lights

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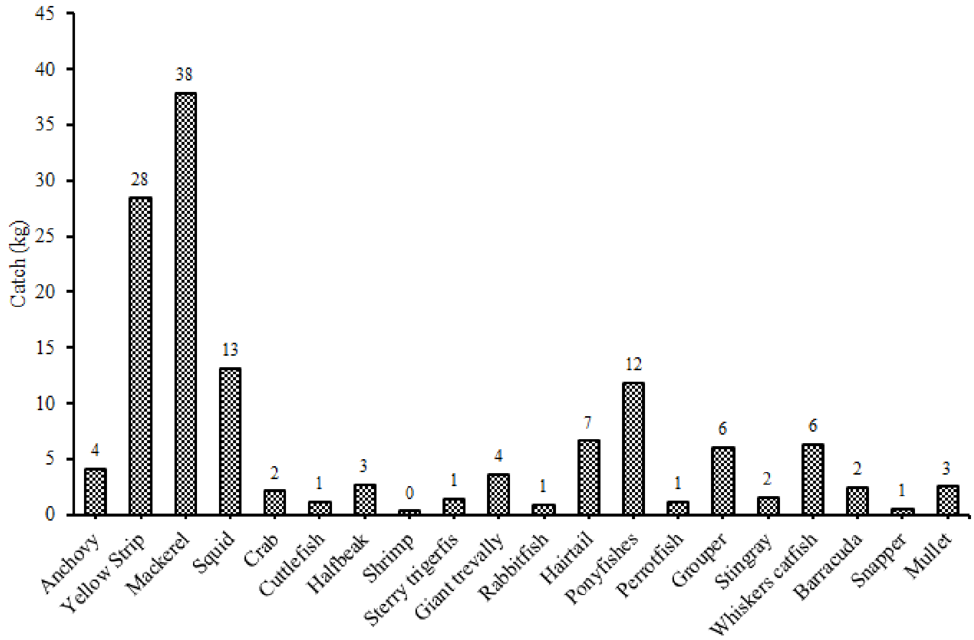

Figure 7 Number and types of fish caught with LED lights

The fish school fluctuations on LED lights were allegedly influenced by groups of predatory fish that prey on small fish (Taufiq *et al*., 2016). The types of fish caught in LED lights were more than those with kerosene lights. There were 20 types of fish caught in the LED light. Each type of fish forms its schools according to its individual preferences. The average number of LED fish catches was 21.06±2.32 kg/trip. The dominant fish caught were mackerel (39 kg or 28%), yellow stripe scads/ *Selar fish* (28 kg or 21%), squid (13 kg or 10%), and ponyfishes/ *Petek fish* (12 kg or 9%) of the total catch. The least caught fish species were snapper and shrimp, 0.5 kg and 0.3 kg, respectively (Figure 7).

The Effectiveness of Kerosene Lights

Kerosene lights use a lampshade to direct the light to a catchable area. The lampshade is placed at the top of the lamps with a diameter of 60 cm. Kerosene lights were placed 2.5m above the water to attract fish. After many fish had arrived, the lamp's position was lowered 1m above the water to concentrate the school of fish. The distribution of the light intensity of the Kerosene lights reached the bottom of the water (13m) and exceeded the width of the stationary lift net (10m). Kerosene lights have a light distribution that is too wide, so it is not easy to concentrate fish during fishing operations. The characteristics of the distribution of light in kerosene lights are very different from that of an LED light. The light of the kerosene lights is evenly distributed to the outside of the stationary lift net. Kerosene lights have light intensity between $3.02x10^{-6}$ -$7.92x10^{-10}$ W/cm^2. The distribution of light from the kerosene lights greatly influences the distribution pattern of fish (Guntur *et al*., 2016). The distribution pattern of fish in kerosene lights tends to be even, and it is not easy to form school. The fish schools formed were little and unstable. They formed at the tenth and fifteenth observation intervals but dispersed again. Fish were scattered at a depth of 4-12m or an intensity of $1x10^{-7}$ to $10x10^{-9}$ W/cm² (Figure 8).

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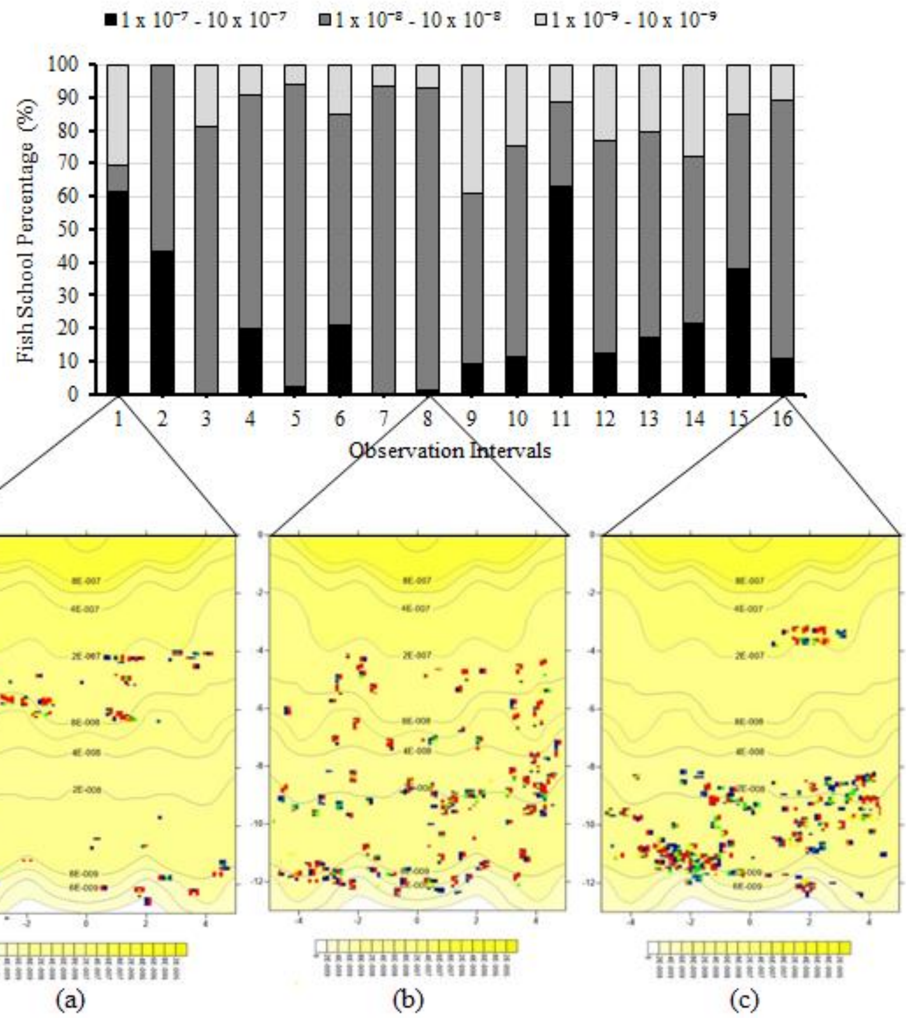

Figure 8 Distribution of fish schools in kerosene lights (a) First interval (b) Eighth interval (c) Sixteenth interval

The distribution of fish schools in kerosene lights was very different from LED lights. The distribution of light from the kerosene lights tends to spread to the sideways of the stationary lift net. Fish schools were evenly distributed from a depth of 4-12m or at a light intensity of $8x10^{-7}$-$2x10^{-9}$ W/cm^2. The fish school formed was small and unstable. The highest average percentage of fish school was found at a depth of 5-9 m or at a light intensity of $1x10^{-8}$-$10x10^{-8}$ W/cm^2, which was 64% (Figure 9). The percentage of fish schools in this area increased from 8% at the first observation interval to 78% at the last observation interval. The highest percentage of fish schools was in the seventh observation interval, 93%, while the lowest percentage of fish schools was in the first observation interval of 8%. The average percentage of fish schools at a depth of 1-5m and 9-12m was the same, 18%. The percentage of fish schools in these two areas tends to decrease with the addition of lighting time. The percentage of fish schools at a depth of 1-5m was 61% at the first observation interval and decreased to 11% at the last observation interval. The percentage of fish schools at a depth of 9-12 m was 31% at the first observation interval and decreased to 11% at the last observation interval.

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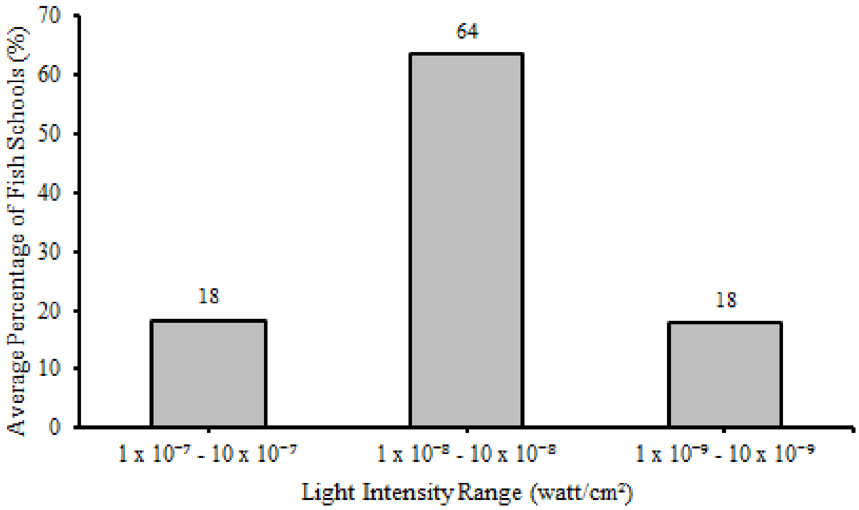

Figure 9 Percentage of fish school in kerosene lights

The characteristics of fish caught in kerosene lights were almost the same as those of LED lights. They indicate that the type of lamps did not affect the characteristics of the fish caught. The dominant fish caught were mackerel, yellow-stripe scad/ *Selar* fish, squid, and ponyfishes/*Petek* fish. The number of mackerel and ponyfishes/*Petek* fish caught in the kerosene lights was 39 kg and 36 kg or 31% and 28% of the total catch, respectively. The squid and ponyfishes/*Petek* fish caught were 10 kg and 9 kg, or about 8% and 7% of the total catch. The average number of fish caught in the kerosene lights was 17.5±1.98 kg/trip. The types of fish caught the least were *Julung-julung* fish and shrimp, which was 0.2 kg (Figure 10).

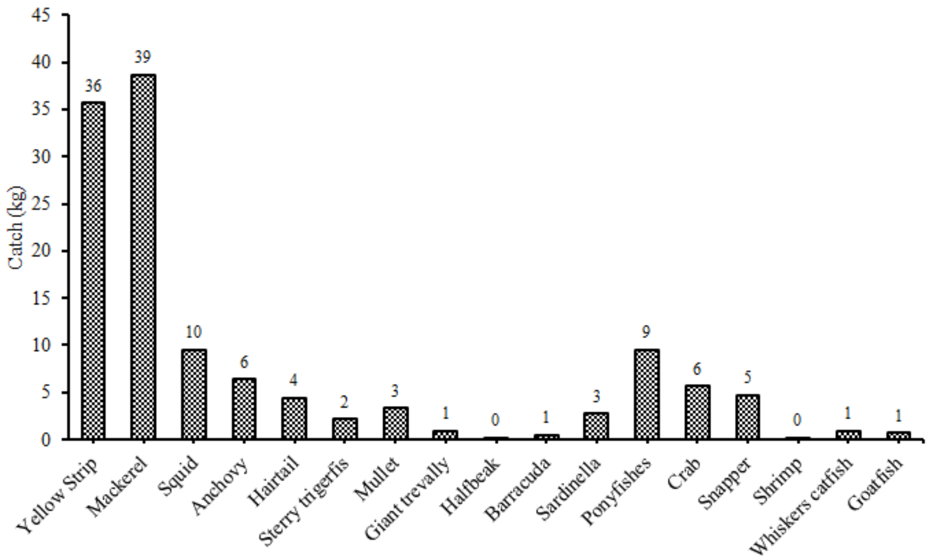

Figure 10 Number and types of fish caught with kerosene lights

Performance tests of LED lights and kerosene lights were conducted in a stationary lift net in Pasuruan waters, East Java, Indonesia. The lamps performance test results showed that LED lights obtained higher average fish catches than kerosene lights. The average catch of LED lights fish was 21.06±2.32 kg/trip, while that of the kerosene lights was 17.5±1.98 kg/trip (Figure 11).

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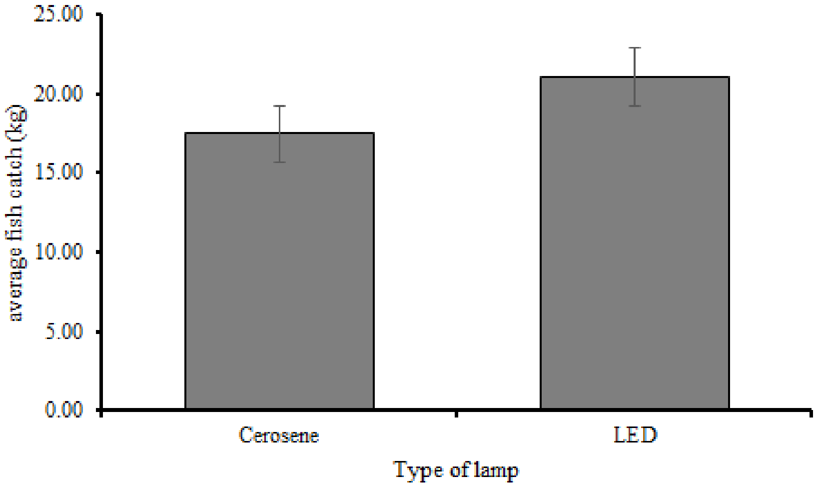

Figure 11 The average catch of LED lights and kerosene lights

The highest fish catch from LED lights was obtained on the second trip of 32.1 kg, while the lowest on the eighth trip was 11.2 kg. The highest fish catch of kerosene lights was obtained on the second trip of 24.6 kg, while the lowest on the third trip was 10.4 kg. Based on the results of the paired t-test, it was shown that the catch of fish in LED lights was significantly different from that of fish caught in kerosene lights. The test results showed that the t-count was 2.4469 while the t-table was 2.3645. The t-count value was more significant than the t-table. The distribution of LED lights has a significant effect on fish catches compared to kerosene lights.

Discussions

Fishing light attractors on a stationary lift net have an essential role in concentrating fish in the catchable area (Riyanto *et al*., 2019). Lights are instruments that can be engineered so that the fishing process runs effectively and efficiently (Sofijanto *et al*., 2019). Fish catching is effective and efficient if its process goes well, obtains optimal catches, and the fishing operation costs are low (Satrya, 2020). Several factors can be engineered so that the fishing process in the stationary lift net runs effectively, including the distribution of light, the intensity and color of the light, and the method of catching fish. Factors of light distribution, intensity, and color of light are closely related to the preference of fish species to light. Each type of fish has a different preference for light (Fuad *et al*., 2020).

Engineering fishing light attractors is critical for running a successful and efficient fishing operation. One of the most significant aspects of meeting the efficiency criteria is using energy-saving lighting (Fajriah *et al*., 2019). Energy-saving lighting will lower the cost of fishing operations. Energy-saving lamps can cut fuel expenditures by up to 77% (Nguyen and Phu., 2015). A Light Emitting Diode (LED) is one type of light that meets energy-saving standards. LED illumination potentially boosts fish catches (Susanto *et al*., 2015; Guntur *et al*., 2015; Nguyen and Phu., 2015; Kehayias *et al*., 2016; Fuad *et al*., 2019). LED lights have properties that make them better suited for fishing light attractors (Hua and Xing 2013).

The light distributions are highly dependent on the medium through which it passes. The distribution of LED light intensity in the air is much greater than the light intensity in the water. The distribution of LED light intensity in the air ranges from 4.17×10^{-2}-1.6×10^{-3} W/cm^2, while the distribution of LED light intensity in the water ranges from 4.27×10^{-6}-9.94×10^{-11} W/cm^2. Differences in light intensity are caused

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by differences in the density of each medium. LED lights have been designed to minimize differences in light intensity across all media. LED lights are designed with a small light beam angle. The beam angle of the LED lights was 120°. A small light beam angle can increase the concentration of light at a certain point (Kehayias *et al*., 2016).

The LED light color has a different distribution of light intensity. The light intensity distribution will decrease with increasing distance from the light source (Puspito *et al*., 2017). The light distribution intensity greatly determines the optimum lighting area. The light distribution intensity is strongly influenced by the turbidity of the waters, the waves, and the light position. Particles in seawater will absorb light energy that propagates through it. The number and density of phytoplankton and zooplankton in seawater also affect the light illumination in the water (Macy *et al*., 1998). The greater the number of plankton and particulates (cloudy), the lighter energy is lost (Yeh *et al*., 2014). Sea waves also significantly affect the distribution of light intensity in the water. Sea waves also greatly determine the turbidity of the waters and the position of the LED lights. The bigger the waves, the more turbid the waters, and the lights' position will continue to change.

Conclusions and Suggestions

The LED light intensity spreads evenly throughout the catchable area of the stationary lift net with an intensity of $1.65x10^{-8}$ W/cm^2 up to $8.64x10^{-10}$ W/cm^2, while the intensity of the kerosene lights is $3.02x10^{-6}$ W/cm^2 to $7.92x10^{-10}$ W/cm^2. Fish prefers the distribution of LED light intensity at $1x10^{-8}$–$10x10^{-8}$ W/cm^2, with fish concentrations reaching 65%. The effectiveness of the LED lights performance is better than that of the kerosene lights, which is indicated by the higher fish catch, which is 21.06±2.32 kg/trip.

The indicators used to measure the effectiveness of the lamp's performance are the catch, the speed of forming a school, and the distribution of fish around the lamps. However, many other indicators have not been used to measure lamps performance, such as fish physiology, behavior, and biochemistry. These three indicators are highly recommended to measure the performance of fishing light attractors.

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