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Suggestions

Editor Comments

1. Reviewer Comments

Fishing with light is an important for the Asian countries, especially. This manuscript is well prepared. The corrections is labelled in the text. Please see the directions.

2. Reviewer Comments

My comments and suggestions are on the text.

Reviewer 1

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Abstract

Fixed lift net fisheries in Banten Bay used compact fluorescent lamp (CFL) since the middle of 2000 for replacement the traditional pressured kerosene lantern. It was increased the light intensity, but this lamps consumed high energy and fuels. Application of light emitting diode (LED) is considered to energy saving and increased catches in lift net fisheries. The fishing trial was conducted on 22 May-16 June 2015 in Banten Bay Indonesia using 2 units of lift net with 6 units of CFL and LED respectively. The result shows both lamps did not have significant effect on total catches. Meanwhile, application of LED lamps has significant effect to main catch (anchovy). There were increasing catch weight of anchovy with mean 29.49%. LED also decreased of fuel consumption with mean saving 35.15%. It is evident enough to conclude that LED lamps have high efficiency and effectiveness for lift net fishing in Banten Bay.

Key word: anchovy, compact fluorescent lamp, light fishing, fuel consumption

1. Introduction

Fishing with light is a successful of modern fishing technique that was ~~developed~~ used in Indonesia since 1950 in various fishing gears. The light fishing gears in Indonesia dominated by lift net (bagan) and purse seine (Sudirman and Musbir, 2009). There are 2 types of bagan in Banten Bay Indonesia, fixed lift net as the small scale fisheries, and boat lift net as the thrive of light fishing activities. Bagan has used compact fluorescent lamp (CFL) as fishing lamps to attract photo taxis positive of fish schooling since 15 years ago. It replaced pressurized kerosene lanterns that were used by fishers before developing of gasoline generator as the electric power source. There are variety of light power (W), number (units), and manufacture of CFL lamps used on bagan fisheries based on traditional knowledge and fishermen experience.

Comment [N1]: Fishing with light is used since ancient times. Please see Ben-yami 1976 Fishing with light.

Fishing lamp is a key component for light fishing activities. The light sources of fishing lamps have developed from torch, acetylene, kerosene, incandescent, mercury, fluorescent, and halogen lamps to the metal halide lamps (Inada and Arimoto, 2007). Fishermen generally think that the catch of light fishing will increase with the rises of light power. However, there are many factors that affect fish attraction such as the quality of light (e.g. wavelength), quantity of light (e.g. power), and arrangement of fishing lights. In addition, underwater illuminance, irradiance level and distribution created by these factors are influenced by the optical characteristics of seawater and influence to the fish behaviour (Arakawa et al., 1998; Shikata et al., 2011).

The scientific basis evident for selecting the appropriate of light source and its power as fishing lamps still remains unverified. Information about the relationship between fishing lights and fish behavior is still limited and consequently fishermen determine the type, number and power of fishing lights based on their personal experience (Yamashita et al., 2012). Meanwhile, light source in fishing attraction by light, which mainly includes filament lamp, halogen tungsten lamp, mercury and metal halide, all belongs to thermal light source (Hua and Xing, 2013). The light from these lamps is omnidirectional and, therefore, most of it does not reach the target areas, such as the deck and the surrounding water (Lai et al., 2015). Although these sources have improved light intensity, their main handicap is that these lamps consumed a great amount of electric energy and fuel (Kehayias et al., 2016).

Compared with these conventional lamps, light emitting diode (LED) have many advantages, such as high efficiency, a long lifetime, fast response and together with climate resistance (Lai et al., 2015). Furthermore, LEDs, which do not contain mercury (as opposed to CFL), are tolerant of low voltages, very small and portable, and have high optical efficiency. LEDs are often submersible, and it can be compared favourably, technically and economically with all other forms of lighting for small-scale applications (McHenry et al., 2014). Thus,

Comment [N2]: Please add as reference Ben-yami 1976

LEDs have been considered the most promising new lighting solution for a fishing fleet. Therefore, the objective of this research is to compare and to analyse the effectiveness of LED lamps application by using catches and fuel consumption indicators. The results from this research can be considered to replace the traditional CFL lamps with LED fishing lamps that was more efficient and environmental friendly to promote sustainable fisheries at Bagan fishing in Banten Bay Indonesia.

2. Material and methods

Lift net fishing in Banten Bay used varies CFL lamps with ranged of output power between 24 W to 90 W per unit. In this research, we tried to introduce the new lamps (LED lamp) and analyzed the effectiveness of both lamps based on catch weight and fuel consumption. Light sources in this experiment are white LED lamps (Fujilight bulb 30 W) and white CFL lamps (Cahaya 3U model 90 W). These lamps were chosen based on several reasons. The CFL lamps are an existing light source that was used by local fishermen because low price, easy to be obtained, and bright enough to attract fish schooling. Meanwhile, LED lamps have very long operating life, small, low energy consumption (Shen et al., 2012; Matsushita and Yamashita, 2012; Hua and Xing, 2013) and they have similar lumens output with CFL lamps based on manufacture specification.

The CFL and LED lamps have different model and construction. They will affect to difference of light distribution of both lamps. To analyze the pattern of light distribution, we investigated the illuminance of both lamps in air and sea water. Measurements of luminous intensity in air were performed in dark room at Fisheries Department Laboratory Sultan

Ageng Tirtayasa University using digital lux meter (Lutron model LX-103 min scale 1 lx). The light intensity distributions were investigated by rotating sensor at every 10-degree with radius 1 m from the light source to the sensor (followed Wisudo et al., 2002).

Comment [N4]: What is the maximum depth for the light sensor? Please add in here.

Fishing operation was conducted at 2 fixed lift net in Banten Bay with coordinate of LED lamps and CFL lamps at 05°58'02"S; 106°09'40"E and 05°58'05"S; 106°09'58"E respectively. The platform size of both bagan was 14 m length, 14 m breadth and 12 m depth. Its box-shaped net was 12 m length and 12 m breadth, with 1 mm mesh size of polyamide. Light illuminance of LED and CFL lamps at night in sea water was measured by underwater lux meter (LUW 1000D) at sea surface to 10 m depth during fishing operation. The measurements were conducted at the centre, middle and corner of platform with 1 m interval (Figure 1).

The first lift net used 6 units of CFL (each lamps is 90 W) and the second bagan used 6 unit LED (each lamps is 30 W) to attract fish schooling into catchable area. The fishing operations were conducted from 7.00 PM to 05.00 AM and the lamps were turned on between 2-4 hours every setting process. The catch data were recorded soon after hauling by sorting the fish based on species, and then weight measured for each species. Fuel consumption of gasoline generator was investigated by adding new fuel using measuring glass every morning after finishing the fishing operation.

Light distribution of LED and CFL lamp in air presented and compared graphically as radar diagram. Luminous intensity of both lamps in sea water shown as graphic of light intensity distribution pattern and describe descriptively. Catch weight (kg) and fuel consumption (l) data were evaluated graphically and performed by t-test analysis ($\alpha = 0.05$). The graphical comparisons of catch weight combined across with fishing trip using total catch, main catch and proportion of main catch that expressed as a percentage of main catch.

3. Results

Distribution pattern of luminous intensity (lux) of the CFL and LED lamps in the air shows in Figure 2. The light distributions of CFL lamp have main area around the left and right side. Meanwhile the LED lamp has majority of illumination on the bottom of the bulb. The maximum intensity of CFL and LED lamps are 775 lx and 783 lx respectively.

Light illuminances in sea water from CFL and LED lamps have different distribution as shows in Figure 3. The LEDs have higher intensity in surface water until 5 m deep than CFLs, but the both light source have similar characteristics at 5 to 10 m deep. Light distribution of LED light is more effective and it has homogenous pattern on vertical and horizontal direction. Meanwhile the CFLs are slightly different on vertical, especially on the centre of lift net that have lower intensity than left and right side. The illumination zone for CFL lamps is narrow than LED lamps and it will affect to catchable area on fish capture process.

A total of 120 operations were conducted on 20 days fishing trip by 2 lift net during 22 May-16 June 2015. There was no fishing trips around the full moon (1-5 June) and fixed lift net located in shallow water of Banten Bay less than 15 m deep. The total catch from 2 lift net is 616.57 kg (mean 15.41 ± 0.15 SD). The highest catches is 310.50 kg on lift net that using CFL lamps. The daily catch of CFLs ranged from 6 to 39 kg (mean 15.53 ± 8.94 SD) and LEDs have varied from 7 to 31 kg (mean 15.30 ± 6.10 SD). Figure 4 shows the daily catch from each lift net during experiment. There are no significant different between the total catch of CFL and LED lamps.

Anchovy (*Stolephorus* sp.) is an economic commodity that becomes main target species of lift net fisheries. Figure 5 shows the daily catch of anchovy during experiment. There are a significant different of catches between LEDs and CFLs on trip 1, 3, 5, 6, 8, 9, 11, 13, 17, 20 respectively. Lift net with CFL lamps get high catches on trip 8, 10 and 19, meanwhile LEDs

have more catches on other fishing trip. The maximum catches of LEDs and CFLs were 15.4 kg (mean 9.82 ± 3.72 SD) and 14.0 kg (mean 8.09 ± 3.11 SD) respectively.

Figure 6 shows the proportion (%) of catches weight of LED and CFL during fishing operation. There are slightly different of catches between LED and CFL almost on every fishing trip. The application of LED lamps can get 25% to 90% of anchovy (mean 67 ± 21 SD), while CFL lamps produce 33% to 83% (mean 58 ± 14 SD). The field experiment of the LED lamps presented no technical problems, especially for the maintenance and replacing the CFL lamps. Specifically, overall increase of main catches using LED lamps of 29%.

The lift net fishing used gasoline generator as a main source of electric power. The maximum output of the generator reaches 2,000 W. Duration for lighting in one day trip approximately 10 hours (07.00 AM to 05.00 PM). Fuel consumption of CFL lamps is higher than LED lamps as shows in Figure 7. Fishing operation using LED lamps consumed 3.30 to 5.30 l/night (mean 4.11 ± 0.61 SD), while CFL lamps consumed 5.20 to 7.00 l/night (mean 6.33 ± 0.54 SD). Fuel consumption rate (l/h) under various lamps showed different tendencies. When all the lamps were turn on, lift net with LED lamps consumed 0.33-5.33 l/h for lighting output 180 W and lift net with CFL lamps consumed 0.52-0.70 l/h against 560 W output.

Figure 8 shows the reduction of fuel consumption (%) on lift net operation using LED lamps. Replacing CFL with LED lamps will decrease of fuel consumption during fishing experiment. Reduction of fuel consumption ranged from 18% to 45% (mean 35.15 ± 7.76 SD). The LED is an appropriate lamp technology for the lift net fisheries especially to reduce fuel consumption and promote the environmental friendly of small scale fisheries in Banten Bay.

4. Discussion

The number of fixed lift net in Banten Bay on 2015 reaches 62 units and most of them used CFL lamps to attract target fishes to the catchable area. Fishermen changed their pressurized kerosene lanterns with CFL lamps since 2000 to increase the productivity of lift net fishing operation. The fishers select appropriate CFL lamps based on practical and economic reasons. In this case, low price, easy to used, easy to be obtained, and bright enough are the main consideration that were underlie by local fishermen to select varies of CFL lamps. Nevertheless, application of high output of CFL lamp (up to 90 W per unit) cause increasing of gasoline fuel consumption during fishing operation.

It is evident from Figure 2 that LED produced high intensity at the bottom of lamps (angle 0° - 40° and 320° - 360°). Meanwhile the CFL transmitted high intensity at both side of lamps (angle 60° - 100° and 260° - 310°). There are significant different of light distribution because each lamps have different shape and constructions. The CFL lamp has more surface area at the side (u-tube construction), so these sections have maximum light distribution. Light emitted from the bottom of CFL comes from the bottom side of u-tube that had limited surface area and causes the decreasing of light intensity from the lamp (Puspito et al., 2015). Moreover, light from LED lamp has straight direction especially to the bottom area. LED light sources are highly directional and highly efficient light emitters that can focus the light intensity (Shen et al., 2012). It causes maximum intensity at the bottom of lamps position. The spectrum, intensity and light distribution of lamps have specific characteristics depends on shape and purpose of lamps manufacture (Anongponyoskun et al., 2011).

Fishermen used iron lamp shade (350 mm diameter) to focus the light during fishing operation. The characteristic of light sources cause different light distribution pattern in sea water, even if it used same lamp shade. LED light distribution had deeper penetration and widely expanded than CFL light. The maximum intensity of LEDs and CFLs at the sea water surface was 2,244 lx and 758 lx respectively on the centre of lift net platform. There were

different pattern of iso-lux contour from each lamps at more than 2 m depth. LED light presented U-shape and CFL light have W-shape that decreased with increasing of depth water. It is related to lamps design, construction and light characteristics from each lamp. Light from LED source have sharp distribution and arrives enough at 15 m depth and have no extreme change in spectrum from the surface to 15 m depth sea water (Okamoto et al., 2008). In this research, lift net fishing operation used the general lighting of LED and CFL lamps that was not designed specifically as fishing lamps. Moreover, the light intensity decrease rapidly related to the emergence angle and it distribution varied at target plane. The lens of LED source with novel design using double freeform surface is an effective method to improve uniformity of light illuminance from 67.20% to 86.43% (Wu et al., 2015).

Catch composition during experiment shows the LEDs fixed lift net dominated by *Stolephorus* sp (61.77%), *Sardinella fimbriata* (14.70%), *Leiognathus* sp (14.20%), *Terapon* sp (3.96) and others species (5.29%). The CFLs catches also dominated by *Stolephorus* sp (59.99%), followed by *Sardinella fimbriata* (22.60%), *Leiognathus* sp (8.18%), *Terapon* sp (5.61) and others species (3.61%). Meanwhile there was no significant difference between daily total catch of each lamp (p-value 0.2218). It means the light illuminance and distribution from both lamps around fixed lift net platform have similar effectiveness to attract fish into catchable area. Mean catch per unit effort in squid jigging fishery using only 216 LED lamps lower than using 78 Metal Halide Lamps, because LED lamps irradiated only a limited area near of vessel (Shikata et al., 2012). Catch weight of boat lift net using flood LED lamps also lower than mercury lamps (Sulaiman et al., 2015). It was indicated the general lighting of LED lamp cannot used directly as effective fishing lamp on capture fisheries. Fish behaviour and response related to light emitted of LED were investigated to improve design and to obtain an appropriate specification of the new generation of fishing lamps in fishing activities (Mills et al., 2014). The new design of white LED lamps used multi-segmented freeform lens

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(MSFL) can perform better as fishing lamps, 3 times more efficient, than the traditional **HID** lamp (Lai et al., 2015).

Comment [N6]: Please not only given the abbreviation

The anchovy as main target species of fixed lift net in Banten Bay has high economic value (**IDR** 75,000 – 90,000 per kg). LED lamps application in this experiment had significant effect to catch weight of anchovy (p-value 0.0087). It is evident from Fig. 5 and Fig. 6 that catches weight and proportion of main catch using LED lamps is higher than CFL lamps. Previous researches show varied result of LED performance in fishing operation. Combination of LED panel with 24 metal halide lamps presented highest catch of Japanese common squid (Yamashita et al. 2012). Light from white LED lamp could penetrate to deeper water and caught more white anchovy (*Stolephorus indicus*) than mercury lamps (Sulaiman et al., 2015a). Blue LED was recommended to gathering the squid and white LED was very useful to squid fishing (Jeong et al., 2013). Fishing experiment using LED and metal halide lamp in Korean squid jigging fisheries presented that catches of squids per the fishing vessel with 1W LED fishing lamp were higher up to 135.5% than the fishing vessel with **MH** (An, 2014). Main catch (*Stolephorus* sp.) per unit energy of boat lift net in Sulawesi using LED and mercury lamp is 11.61 kg/W and 3.77 kg/W respectively (Sulaiman et al., 2015b).

Comment [N7]: Please not only given the abbreviation

Comment [N8]: Japonica or japonicus??? Please see fishbase.org

White LED in this research have dominant wavelength at 450 nm and 590 nm. It is similar properties with Bae et al. (2011) that used the dominant wavelength of white LED at 450 nm and 550 nm to attract *Engraulis japonica*. Characteristic of fishing lamps will have affected to catch weight and species composition. It is related to behaviour and response of fish to light attractant. Each species has different maximum absorbance of light spectrum depend on structure and morphology of retinae. *Stolephorus indicus* have poly-cone type with cone density $684 \times 10^4 \mu\text{m}^2$. It is indicate that retinae of this species very adapted to light stimulant (Heb et al., 2006). *Engraulis japonicus* and *Engraulis encrasicolus* have triple cone with maximum absorbance wavelength approximately at 502 nm, while the short central

components were more shortwave sensitive ($\alpha_{\max} = 475 \text{ nm}$). The α_{\max} of all long and short cones in the ventro-temporal zone was 492 nm, compared to 502 nm in other retinal regions (Kondrashev et al., 2012). The dominant catch of *Stolephorus* sp. during experiment indicated the transmitted wavelengths from LED lamps were appropriate enough to the maximum absorbance of anchovy. It schooling influenced, gathering and stay into catchable area for the long times as a response of light adaptation behaviour.

LED lamps had lower fuel consumption than CFL during fishing operation. It is evident from Fig. 7 and Fig. 8 that LED is efficient light source with mean saving energy up to 35%. Application LED lamps in fixed lift net in Banten Bay had significant effect to reduce fuel consumption (p-value 5.01×10^{-14}). LED fishing lamps in hair-tail angling at Korean fisheries had higher fishing performance, save 33% of fuel consumption, decreased the operation expenses and green house emission (An et al., 2012). Fishing experiment at purse seine and squid jigging fisheries showed LED lamps have high productivity and lower fuel consumption than metal halide lamps. LED lamps save 50% of fuel than metal halide (Hua and Xing 2013), more efficient up to 80% than high intensity discharge (Shen et al., 2012) and save 24% of fuel in Japanese squid jigging fisheries (Matshushita et al., 2012). Application LED lamps in Korean squid jigging industries also decreased 65,163 kl of fuel consumption in a year (Park et al., 2015). In small scale fisheries, replacing CFL lamps with LED lamps save 37.5% of fuel consumption in fixed lift net at Lesung Cape Banten Province (Arif et al., 2015).

In conclusions, we found the light distribution of commercial LED lamps could penetrate wider and deeper to the catchable area than CFL lamps and were good enough to attract the target species (anchovy). Application of LED lamps had significant effect to the catch weight of anchovy (mean increase $29.49\% \pm 2.90 \text{ SE}$) and save fuel consumption (mean $35.15\% \pm 0.39 \text{ SE}$). The LED lamps are the potential suitable light source for replacing CFL lamps and developing sustainable lift net fisheries in Banten Bay.

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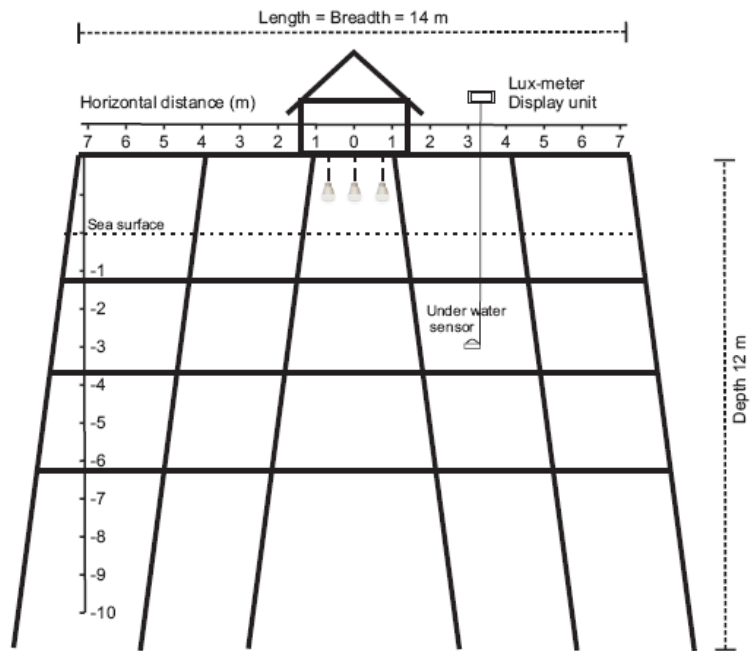


Figure 1 The arrangement of light intensity measurement in sea water

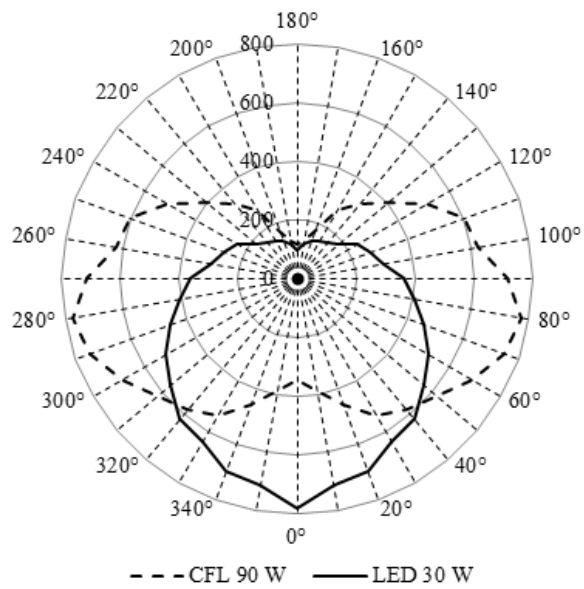


Figure 2 Distribution of light intensity of CFL and LED lamps in the air

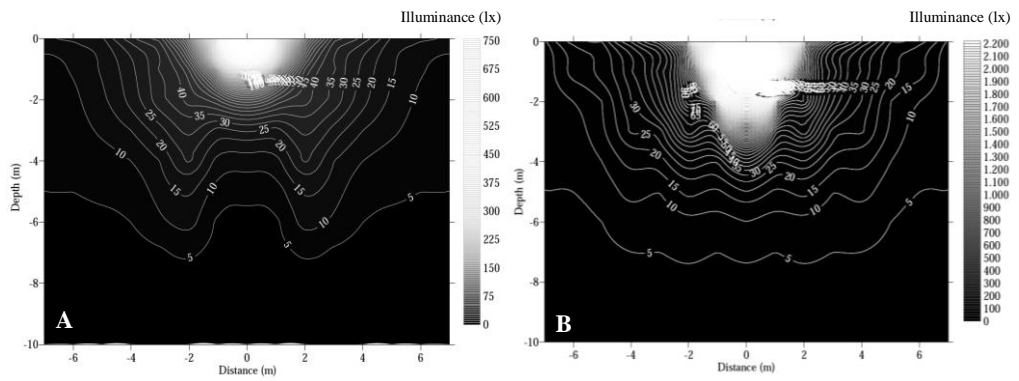


Figure 3 Sea water light distribution of CFL (A) and LED (B) lamps

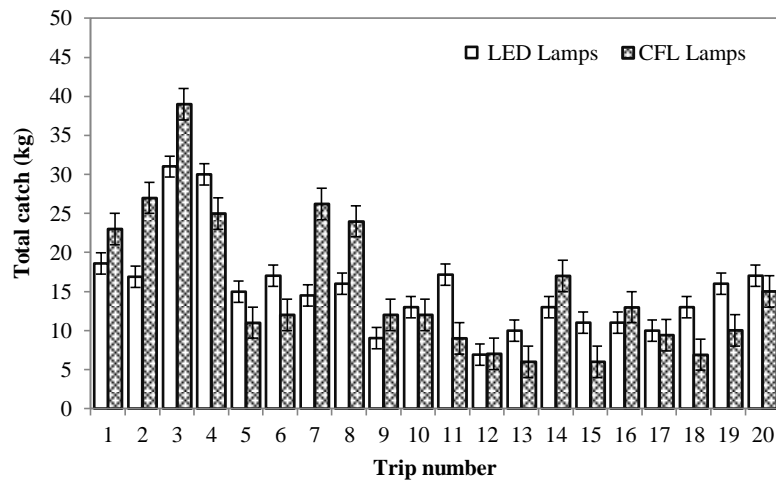


Figure 4 Daily catch of CFLs and LEDs lamps. Vertical lines denote standard errors.

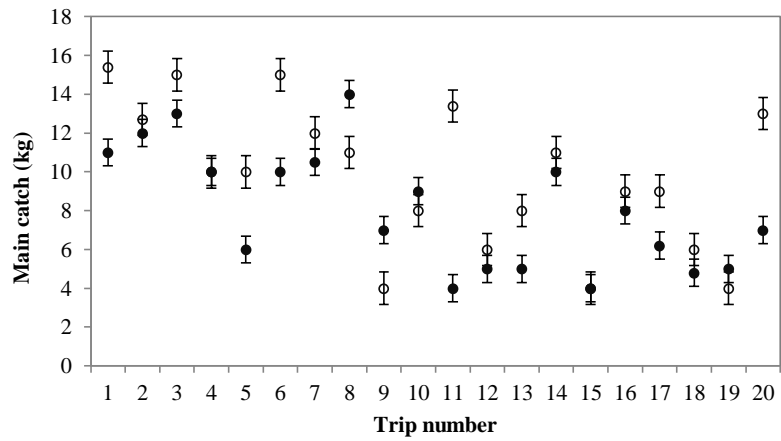


Figure 5 Daily main catches of lift net with LED (open circle) and CFL (black circle).

Vertical lines denote standard errors.

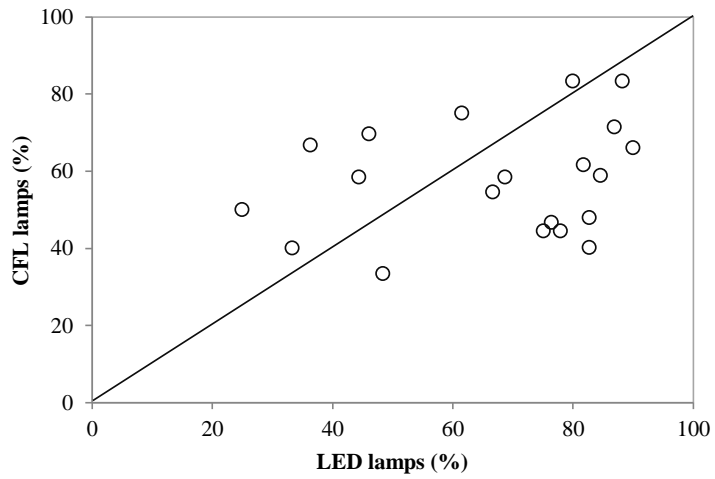


Figure 6 Proportion (%) of lift net main catches using LED lamps plotted against CFL lamps

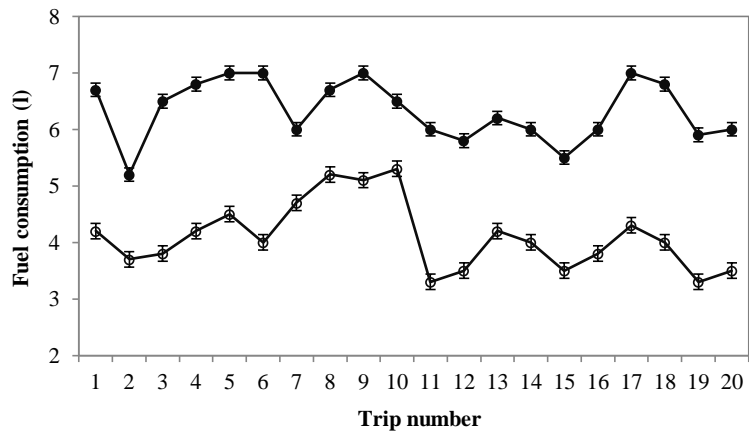


Figure 7 Fuel consumption of lift net using LED (open circle) and CFL (black circle). Vertical lines denote standard errors.

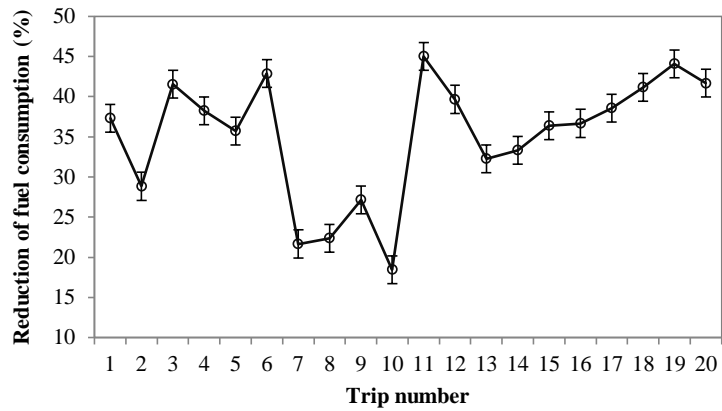


Figure 8 Reduction of fuel consumption of fixed lift net using LED lamps. Vertical lines denote standard errors.

Abstract

Fixed lift net fisheries in Banten Bay used compact fluorescent lamp (CFL) since the middle of 2000 for replacement the traditional pressured kerosene lantern. It was increased the light intensity, but this lamps consumed high energy and fuels. Application of light emitting diode (LED) is considered to energy saving and increased catches in lift net fisheries. The fishing trial was conducted on 22 May-16 June 2015 in Banten Bay Indonesia using 2 units of lift net with 6 units of CFL and LED respectively. The result shows both lamps did not have significant effect on total catches. Meanwhile, application of LED lamps has significant effect to main catch (~~anchovy~~)that anchovy. There were increasing catch weight of anchovy with mean 29.49%. LED also decreased of fuel consumption with mean saving 35.15%. It is evident enough to conclude that LED lamps have high efficiency and effectiveness for lift net fishing in Banten Bay.

Key word: anchovy, compact fluorescent lamp, light fishing, fuel consumption

1. Introduction

Fishing with light is a successful of modern fishing technique that was developed in Indonesia since 1950 in various fishing gears. The light fishing gears in Indonesia dominated by lift net (bagan) and purse seine (Sudirman and Musbir, 2009). There are 2 types of bagan in Banten Bay Indonesia, fixed lift net as the small scale fisheries, and boat lift net as the thrive of light fishing activities. Bagan has used compact fluorescent lamp (CFL) as fishing lamps to attract photo taxis positive of fish schooling since 15 years ago. It replaced pressurized kerosene lanterns that were used by fishers before developing of gasoline generator as the electric power source. There are variety of light power (W), number (of light units), and manufacture of CFL lamps used on bagan fisheries based on traditional knowledge and fishermen experience.

Fishing lamp is a key component for light fishing activities. The light sources of fishing lamps have developed from torch, acetylene, kerosene, incandescent, mercury, fluorescent, and halogen lamps to the metal halide lamps (Inada and Arimoto, 2007). Fishermen generally think that the catch of light fishing will increase with the rises of light power. However, there are many factors that affect fish attraction such as the quality of light (e.g. wavelength), quantity of light (e.g. power), and arrangement of fishing lights. In addition, underwater illuminance, irradiance level and distribution created by these factors are influenced by the optical characteristics of seawater and influence to the fish behaviour (Arakawa et al., 1998; Shikata et al., 2011).

The scientific basis evident for selecting the appropriate of light source and its power as fishing lamps still remains unverified. Information about the relationship between fishing lights and fish behavior is still limited and consequently fishermen determine the type, number and power of fishing lights based on their personal experience (Yamashita et al., 2012). Meanwhile, light source in fishing attraction by light, which mainly includes filament lamp, halogen tungsten lamp, mercury and metal halide, all belongs to thermal light source (Hua and Xing, 2013). The light from these lamps is omnidirectional and, therefore, most of it does not reach the target areas, such as the deck and the surrounding water (Lai et al., 2015). Although these sources have improved light intensity, their main handicap is that these lamps consumed a great amount of electric energy and fuel (Kehayias et al., 2016).

Compared with these conventional lamps, ~~light emitting diode~~ (LED (light emitting diode)) have many advantages, such as high efficiency, a long lifetime, fast response and together with climate resistance (Lai et al., 2015). Furthermore, LEDs, which do not contain mercury (as opposed to CFL), are tolerant of low voltages, very small and portable, and have high optical efficiency. LEDs are often submersible, and it can be compared favourably, technically and economically with all other forms of lighting for small-scale applications

(McHenry et al., 2014). Thus, LEDs have been considered the most promising new lighting solution for a fishing fleet. ~~Therefore,~~

The objective of this research is to compare and to analyse the effectiveness of LED lamps application by using catches and fuel consumption indicators. The results from this research can be considered to replace the traditional CFL lamps with LED fishing lamps that was more efficient and environmental friendly to promote sustainable fisheries at Bagan fishing in Banten Bay Indonesia.

2. Material and methods

Lift net fishing in Banten Bay used varies CFL lamps with ranged of output power between 24 W to 90 W per unit. In this research, we tried to introduce the new lamps (LED lamps) and ~~analyzed~~ analysed the effectiveness of both lamps based on catch weight and fuel consumption. Light sources in this experiment are white LED lamps (Fujilight bulb 30 W) and white CFL lamps (Cahaya 3U model 90 W). These lamps were chosen based on several reasons. The CFL lamps are an existing light source that was used by local fishermen because low price, easy to be obtained, and bright enough to attract fish schooling. Meanwhile, LED lamps have very long operating life, small, low energy consumption (Shen et al., 2012; Matsushita and Yamashita, 2012; Hua and Xing, 2013) and they have similar lumens output with CFL lamps based on manufacture specification.

The CFL and LED lamps have different model and construction. They will affect to difference of light distribution of both lamps. To ~~analyze~~ analyse the pattern of light

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distribution, we investigated the illuminance of both lamps in air and [bottom of the](#) sea water. Measurements of luminous intensity in air were performed in dark room at Fisheries Department Laboratory Sultan Ageng Tirtayasa University using digital lux meter (Lutron model LX-103 min scale 1 lx). The light intensity distributions were investigated by rotating sensor at every 10-degree with radius 1 m from the light source to the sensor ([followed](#) Wisudo et al., 2002).

Fishing operation was conducted at 2 fixed lift net in Banten Bay with coordinate of LED [lamps](#) and CFL lamps at 05°58'02"S; 106°09'40"E and 05°58'05"S; 106°09'58"E, respectively. The platform size of both bagan was 14 m length, 14 m breadth and 12 m depth. Its box-shaped net was 12 m length and 12 m breadth, with [1 mm](#) mesh size of polyamide. Light illuminance of LED and CFL lamps at night in sea water was measured by underwater lux meter (LUW 1000D) at sea surface to 10 m depth during fishing operation. The measurements were conducted at the centre, middle and corner of platform with 1 m interval (Figure 1).

The first lift net used 6 units of CFL (each lamps is 90 W) and the second bagan used 6 unit LED (each lamps is 30 W) to attract fish schooling into catchable area. The fishing operations were conducted from 7:00 PM to 05:00 AM and the lamps were turned on between 2-4 hours every setting process. The catch data were recorded soon after hauling by sorting the fish based on species, and then weight measured for each species. Fuel consumption of gasoline generator was investigated by adding new fuel using measuring glass every morning after finishing the fishing operation.

Light distribution of LED and CFL lamp in air presented and compared graphically as radar diagram. Luminous intensity of both lamps in sea water shown as graphic of light intensity distribution pattern and describe descriptively. Catch weight (kg) and fuel consumption (l) data were evaluated graphically and performed by *t*-test analysis ($\alpha = 0.05$).

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The graphical comparisons of catch weight combined across with fishing trip using total catch, main catch and proportion of main catch that expressed as a percentage of main catch.

3. Results

Distribution pattern of luminous intensity (lux) of the CFL and LED lamps in the air shows in Figure 2. The light distributions of CFL lamp have main area around the left and right side. Meanwhile the LED lamp has majority of illumination on the bottom of the bulb. The maximum intensity of CFL and LED lamps are 775 lx and 783 lx respectively.

Light illuminances in sea water from CFL and LED lamps have different distribution as shows in Figure 3. The LEDs have higher intensity in surface water until 5 m deep than CFLs, but the both light source have similar characteristics at 5 to 10 m deep. Light distribution of LED light is more effective and it has homogenous pattern on vertical and horizontal direction. Meanwhile the CFLs are slightly different on vertical, especially on the centre of lift net that have lower intensity than left and right side. The illumination zone for CFL lamps is narrow than LED lamps and it will affect to catchable area on fish capture process.

A total of 120 operations were conducted on 20 days fishing trip by 2 lift net during 22 May-16 June 2015. There was no fishing trips around the full moon (1-5 June) and fixed lift net located in shallow water of Banten Bay less than 15 m deep. The total catch from 2 lift net is 616.57 kg (mean 15.41 ± 0.15 SD). The highest catches is 310.50 kg on lift net that using CFL lamps. The daily catch of CFLs ranged from 6 to 39 kg (mean 15.53 ± 8.94 SD) and LEDs have varied from 7 to 31 kg (mean 15.30 ± 6.10 SD). Figure 4 shows the daily catch from each lift net during experiment. There are no significant different between the total catch of CFL and LED lamps.

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Anchovy (*Stolephorus* sp.) is an economic commodity that becomes main target species of lift net fisheries. Figure 5 shows the daily catch of anchovy during experiment. There are a significant different of catches between LEDs and CFLs on trip 1, 3, 5, 6, 8, 9, 11, 13, 17, and 20, respectively. Lift net with CFL lamps get high catches on trip 8, 10 and 19, meanwhile LEDs have more catches on other fishing trip. The maximum catches of LEDs and CFLs were 15.4 kg (mean 9.82 ± 3.72 SD) and 14.0 kg (mean 8.09 ± 3.11 SD) respectively.

Figure 6 shows the proportion (%) of catches weight of LED and CFL during fishing operation. There are slightly different of catches between LED and CFL almost on every fishing trip. The application of LED lamps can get 25% to 90% of anchovy (mean 67 ± 21 SD), while CFL lamps produce 33% to 83% (mean 58 ± 14 SD). The field experiment of the LED lamps presented no technical problems, especially for the maintenance and replacing the CFL lamps. Specifically, overall increase of main catches using LED lamps of 29%.

The lift net fishing used gasoline generator as a main source of electric power. The maximum output of the generator reaches 2,000 W. Duration for lighting in one day trip approximately 10 hours (07:00 AM to 05:00 PM). Fuel consumption of CFL lamps is higher than LED lamps as shows in Figure 7. Fishing operation using LED lamps consumed 3.30 to 5.30 l/night (mean 4.11 ± 0.61 SD), while CFL lamps consumed 5.20 to 7.00 l/night (mean 6.33 ± 0.54 SD). Fuel consumption rate (l/h) under various lamps showed different tendencies. When all the lamps were turn on, lift net with LED lamps consumed 0.33-5.33 l/h for lighting output 180 W and lift net with CFL lamps consumed 0.52-0.70 l/h against 560 W output.

Figure 8 shows the reduction of fuel consumption (%) on lift net operation using LED lamps. Replacing CFL with LED lamps will decrease of fuel consumption during fishing experiment. Reduction of fuel consumption ranged from 18% to 45% (mean 35.15 ± 7.76 SD). The LED is an appropriate lamp technology for the lift net fisheries especially to reduce fuel consumption and promote the environmental friendly of small scale fisheries in Banten Bay.

4. Discussion

The number of fixed lift net in Banten Bay on 2015 reaches 62 units and most of them used CFL lamps to attract target fishes to the catchable area. Fishermen changed their pressurized kerosene lanterns with CFL lamps since 2000 to increase the productivity of lift net fishing operation. The fishers select appropriate CFL lamps based on practical and economic reasons. In this case, low price, easy to used, easy to be obtained, and bright enough are the main consideration that were underlie by local fishermen to select varies of CFL lamps. Nevertheless, application of high output of CFL lamp (up to 90 W per unit) cause increasing of gasoline fuel consumption during fishing operation.

It is evident from Figure 2 that LED produced high intensity at the bottom of lamps (angle 0° - 40° and 320° - 360°). Meanwhile the CFL transmitted high intensity at both side of lamps (angle 60° - 100° and 260° - 310°). There are significant different of light distribution because each lamps have different shape and constructions. The CFL lamp has more surface area at the side (u-tube construction), so these sections have maximum light distribution. Light emitted from the bottom of CFL comes from the bottom side of u-tube that had limited surface area and causes the decreasing of light intensity from the lamp (Puspito et al., 2015). Moreover, light from LED lamp has straight direction especially to the bottom area. LED light sources are highly directional and highly efficient light emitters that can focus the light intensity (Shen et al., 2012). It causes maximum intensity at the bottom of lamps position. The spectrum, intensity and light distribution of lamps have specific characteristics depends on shape and purpose of lamps manufacture (Anongponyoskun et al., 2011).

Fishermen used iron lamp shade (350 mm diameter) to focus the light during fishing operation. The characteristic of light sources cause different light distribution pattern in sea

water, even if it used same lamp shade. LED light distribution had deeper penetration and widely expanded than CFL light. The maximum intensity of LEDs and CFLs at the sea water surface was 2,244 lx and 758 lx respectively on the centre of lift net platform. There were different pattern of iso-lux contour from each lamps at more than 2 m depth. LED light presented U-shape and CFL light have W-shape that decreased with increasing of depth water. It is related to lamps design, construction and light characteristics from each lamp. Light from LED source have sharp distribution and arrives enough at 15 m depth and have no extreme change in spectrum from the surface to 15 m depth sea water (Okamoto et al., 2008). In this research, lift net fishing operation used the general lighting of LED and CFL lamps that was not designed specifically as fishing lamps. Moreover, the light intensity decrease rapidly related to the emergence angle and it distribution varied at target plane. The lens of LED source with novel design using double freeform surface is an effective method to improve uniformity of light illuminance from 67.20% to 86.43% (Wu et al., 2015).

Catch composition during experiment shows the LEDs fixed lift net dominated by *Stolephorus* sp (61.77%), *Sardinella fimbriata* (14.70%), *Leiognathus* sp (14.20%), *Terapon* sp (3.96) and others species (5.29%). The CFLs catches also dominated by *Stolephorus* sp (59.99%), followed by *Sardinella fimbriata* (22.60%), *Leiognathus* sp (8.18%), *Terapon* sp (5.61) and others species (3.61%). Meanwhile there was no significant difference between

daily total catch of each lamp (p-value 0.2218). It means the light illuminance and distribution from both lamps around fixed lift net platform have similar effectiveness to attract fish into catchable area. Mean catch per unit effort in squid jigging fishery using only 216 LED lamps lower than using 78 Metal Halide Lamps, because LED lamps irradiated only a limited area near of vessel (Shikata et al., 2012). Catch weight of boat lift net using flood LED lamps also lower than mercury lamps (Sulaiman et al., 2015). It was indicated the general lighting of LED lamp cannot used directly as effective fishing lamp on capture fisheries. Fish behaviour

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and response related to light emitted of LED were investigated to improve design and to obtain an appropriate specification of the new generation of fishing lamps in fishing activities (Mills et al., 2014). The new design of white LED lamps used multi-segmented freeform lens (MSFL) can perform better as fishing lamps, 3 times more efficient, than the traditional HID lamp (Lai et al., 2015).

The anchovy as main target species of fixed lift net in Banten Bay has high economic value (IDR 75,000 – 90,000 per kg). LED lamps application in this experiment had significant effect to catch weight of anchovy (p-value 0.0087). It is evident from Figure 5 and Figure 6 that catches weight and proportion of main catch using LED lamps is higher than CFL lamps. Previous researches show varied result of LED performance in fishing operation. Combination of LED panel with 24 metal halide lamps presented highest catch of Japanese common squid (Yamashita et al. 2012). Light from white LED lamp could penetrate to deeper water and caught more white anchovy (*Stolephorus indicus*) than mercury lamps (Sulaiman et al., 2015a). Blue LED was recommended to gathering the squid and white LED was very useful to squid fishing (Jeong et al., 2013). Fishing experiment using LED and metal halide lamp in Korean squid jigging fisheries presented that catches of squids per the fishing vessel with 1_W LED fishing lamp were higher up to 135.5% than the fishing vessel with MH (An, 2014). Main catch (*Stolephorus* sp.) per unit energy of boat lift net in Sulawesi using LED and mercury lamp is 11.61 kg/W and 3.77 kg/W respectively (Sulaiman et al., 2015b).

White LED in this research have dominant wavelength at 450 nm and 590 nm. It is similar properties with Bae et al. (2011) that used the dominant wavelength of white LED at 450 nm and 550 nm to attract *Engraulis japonica*. Characteristic of fishing lamps will have affected to catch weight and species composition. It is related to behaviour and response of fish to light attractant. Each species has different maximum absorbance of light spectrum depend on structure and morphology of retinae. *Stolephorus indicus* have poly-cone type with

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cone density $684 \times 10^4 \mu\text{m}^2$. It is indicate that retinae of this species very adapted to light stimulant (Heb et al., 2006). *Engraulis japonicus* and *Engraulis encrasicolus* have triple cone with maximum absorbance wavelength approximately at 502 nm, while the short central components were more shortwave sensitive ($\alpha_{\text{max}} = 475 \text{ nm}$). The α_{max} of all long and short cones in the ventro-temporal zone was 492 nm, compared to 502 nm in other retinal regions (Kondrashev et al., 2012). The dominant catch of *Stolephorus* sp. during experiment indicated the transmitted wavelengths from LED lamps were appropriate enough to the maximum absorbance of anchovy. It schooling influenced, gathering and stay into catchable area for the long times as a response of light adaptation behaviour.

LED lamps had lower fuel consumption than CFL during fishing operation. It is evident from [Figure- 7](#) and [Fig-8](#) that LED is efficient light source with mean saving energy up to 35%. Application LED lamps in fixed lift net in Banten Bay had significant effect to reduce fuel consumption (p-value 5.01×10^{-14}). LED fishing lamps in hair-tail angling at Korean fisheries had higher fishing performance, save 33% of fuel consumption, decreased the operation expenses and green house emission (An et al., 2012). Fishing experiment at purse seine and squid jigging fisheries showed LED lamps have high productivity and lower fuel consumption than metal halide lamps. LED lamps save 50% of fuel than metal halide (Hua and Xing 2013), more efficient up to 80% than high intensity discharge (Shen et al., 2012) and save 24% of fuel in Japanese squid jigging fisheries (Matshushita et al., 2012). Application LED lamps in Korean squid jigging industries also decreased 65,163 kl of fuel consumption in a year (Park et al., 2015). In small scale fisheries, replacing CFL lamps with LED lamps save 37.5% of fuel consumption in fixed lift net at Lesung Cape Banten Province (Arif et al., 2015).

In conclusions, we found the light distribution of commercial LED lamps could penetrate wider and deeper to the catchable area than CFL lamps and were good enough to attract the

target species ~~of (anchovy)~~. Application of LED lamps had significant effect to the catch weight of anchovy (~~mean increase 29.49%±2.90 SE~~) and save fuel consumption (~~mean 35.15%±0.39 SE~~). The LED lamps are the potential suitable light source for replacing CFL lamps and developing sustainable lift net fisheries in Banten Bay.

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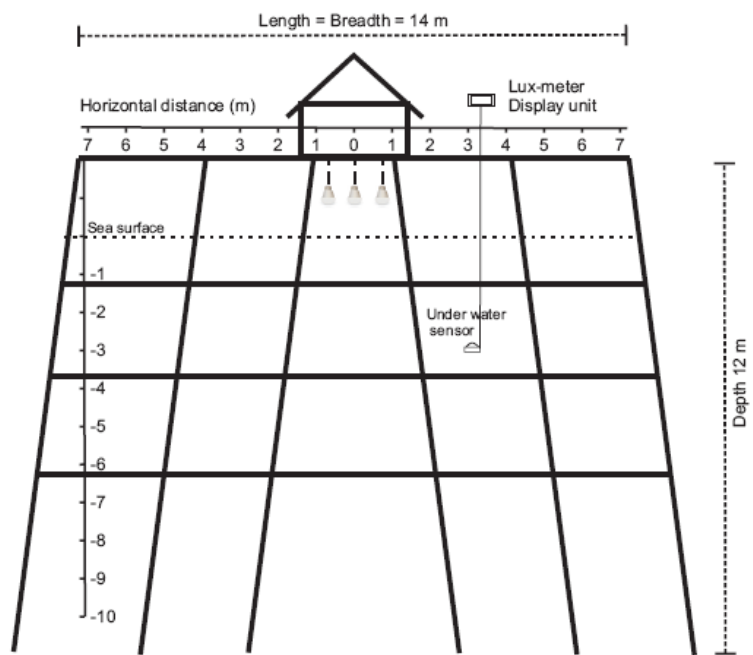


Figure 1. The arrangement of light intensity measurement in sea water.

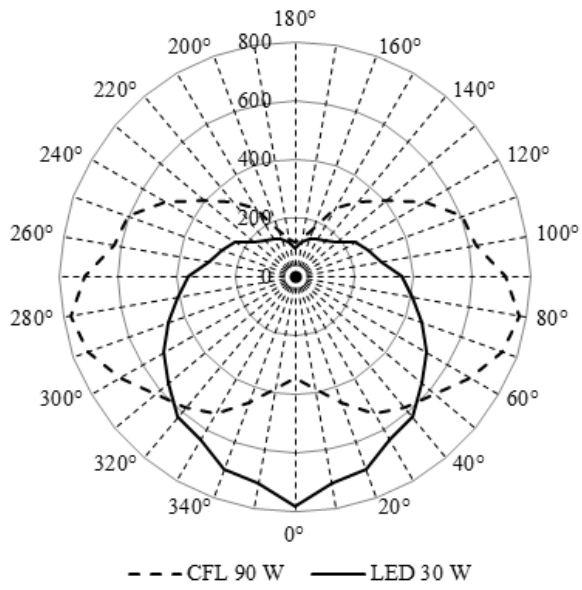


Figure 2. Distribution of light intensity of CFL and LED lamps in the air.

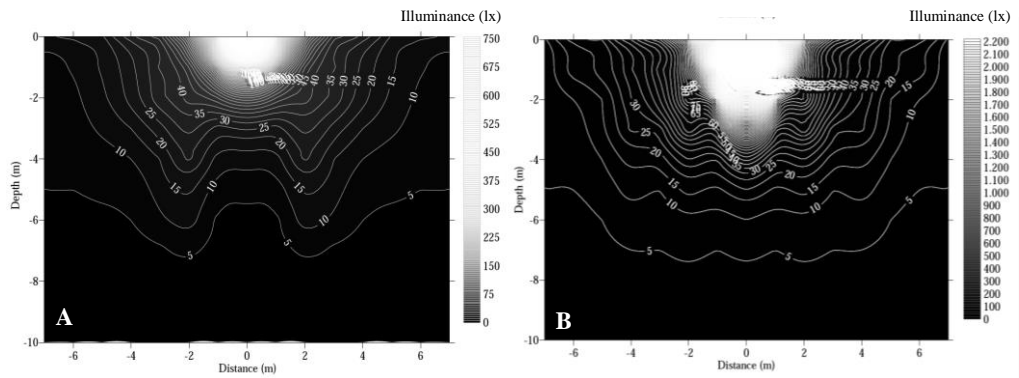


Figure 3. Sea water light distribution of CFL (A) and LED (B) lamps.

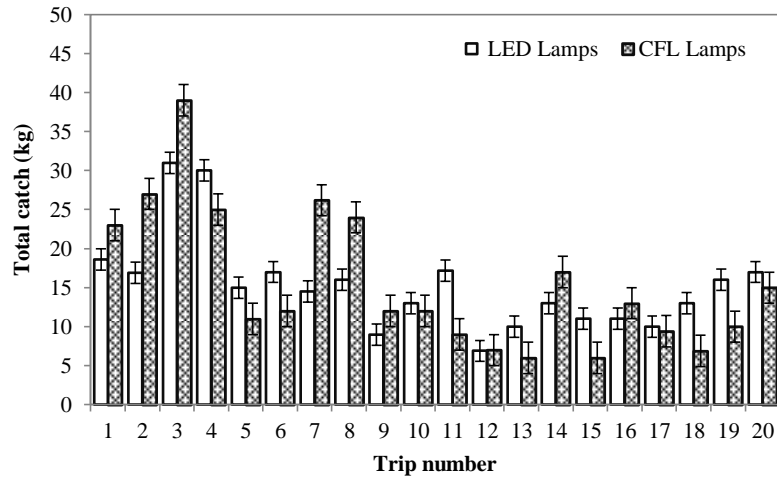


Figure 4. Daily catch of CFLs and LEDs lamps. (Vertical lines denote standard errors).

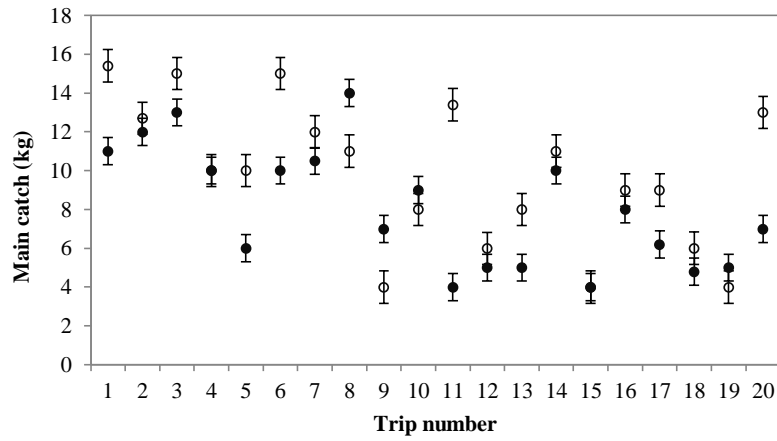


Figure 5. Daily main catches of lift net with LED (open circle) and CFL (black circle point). (Vertical lines denote standard errors).

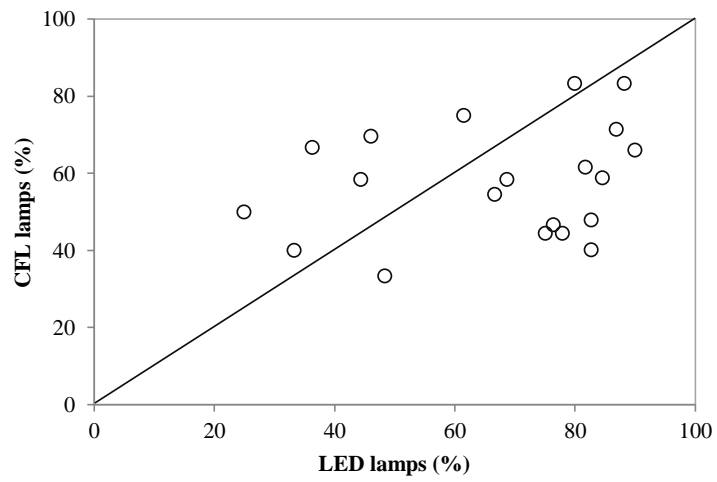


Figure 6. Proportion (%) of lift net main catches using LED lamps plotted against CFL lamps.

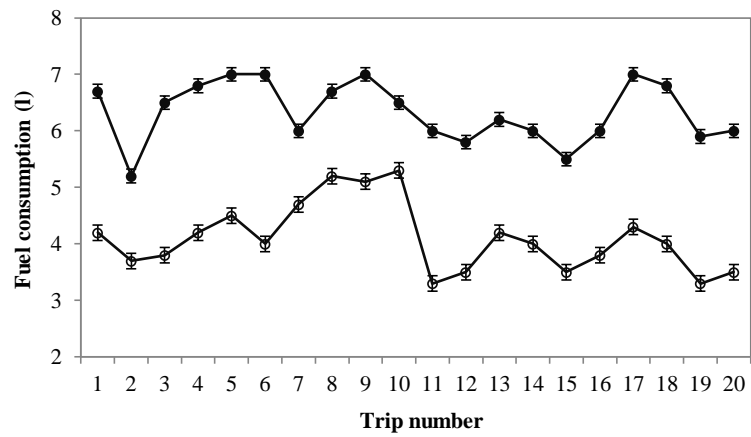


Figure 7. Fuel consumption of lift net using LED (open circle) and CFL (black circle point). (Vertical lines denote standard errors).

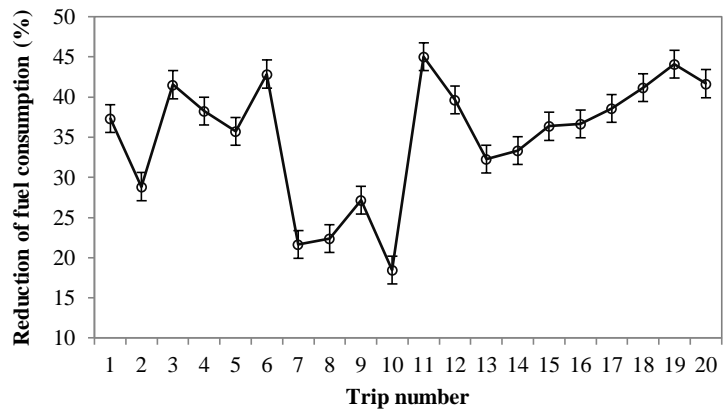


Figure 8. Reduction of fuel consumption of fixed lift net using LED lamps. (Vertical lines denote standard errors).

Abstract

Fixed lift net fisheries in Banten Bay used compact fluorescent lamp (CFL) since the middle of 2000 for replacement the traditional pressured kerosene lantern. It was increased the light intensity, but this lamps consumed high energy and fuels. Application of light emitting diode (LED) is considered to energy saving and increased catches in lift net fisheries. The fishing trial was conducted on 22 May-16 June 2015 in Banten Bay Indonesia using 2 units of lift net with 6 units of CFL and LED respectively. The result shows both lamps did not have significant effect on total catches. Meanwhile, application of LED lamps has significant effect to main catch that anchovy. There were increasing catch weight of anchovy with mean 29.49%. LED also decreased of fuel consumption with mean saving 35.15%. It is evident enough to conclude that LED lamps have high efficiency and effectiveness for lift net fishing in Banten Bay.

Key word: anchovy, compact fluorescent lamp, light fishing, fuel consumption

1. Introduction

Fishing with light is a successful of modern fishing technique that was used in Indonesia since 1950 in various fishing gears (Ben-Yami 1976). The light fishing gears in Indonesia dominated by lift net (bagan) and purse seine (Sudirman and Musbir, 2009). There are 2 types of bagan in Banten Bay Indonesia, fixed lift net as the small scale fisheries, and boat lift net as the thrive of light fishing activities. Bagan has used compact fluorescent lamp (CFL) as fishing lamps to attract photo taxis positive of fish schooling since 15 years ago. It replaced pressurized kerosene lanterns that were used by fishers before developing of gasoline generator as the electric power source. There are variety of light power (W), number of light units, and manufacture of CFL lamps used on bagan fisheries based on traditional knowledge and fishermen experience.

26 Fishing lamp is a key component for light fishing activities. The light sources of fishing
27 lamps have developed from torch, acetylene, kerosene, incandescent, mercury, fluorescent,
28 and halogen lamps to the metal halide (MH) lamps (Inada and Arimoto, 2007; Ben-Yami,
29 1976). Fishermen generally think that the catch of light fishing will increase with the rises of
30 light power. However, there are many factors that affect fish attraction such as the quality of
31 light (e.g. wavelength), quantity of light (e.g. power), and arrangement of fishing lights. In
32 addition, underwater illuminance, irradiance level and distribution created by these factors are
33 influenced by the optical characteristics of seawater and influence to the fish behaviour
34 (Arakawa et al., 1998; Shikata et al., 2011).

35 The scientific basis evident for selecting the appropriate of light source and its power as
36 fishing lamps still remains unverified. Information about the relationship between fishing
37 lights and fish behavior is still limited and consequently fishermen determine the type,
38 number and power of fishing lights based on their personal experience (Yamashita et al.,
39 2012). Meanwhile, light source in fishing attraction by light, which mainly includes filament
40 lamp, halogen tungsten lamp, mercury and metal halide, all belongs to thermal light source
41 (Hua and Xing, 2013). The light from these lamps is omnidirectional and, therefore, most of it
42 does not reach the target areas, such as the deck and the surrounding water (Lai et al., 2015).
43 Although these sources have improved light intensity, their main handicap is that these lamps
44 consumed a great amount of electric energy and fuel (Kehayias et al., 2016).

45 Compared with these conventional lamps, LED (light emitting diode) have many
46 advantages, such as high efficiency, a long lifetime, fast response and together with climate
47 resistance (Lai et al., 2015). Furthermore, LEDs, which do not contain mercury (as opposed to
48 CFL), are tolerant of low voltages, very small and portable, and have high optical efficiency.
49 LEDs are often submersible, and it can be compared favourably, technically and economically

50 with all other forms of lighting for small-scale applications (McHenry et al., 2014). Thus,
51 LEDs have been considered the most promising new lighting solution for a fishing fleet.

52 The objective of this research is to compare and to analyse the effectiveness of LED
53 lamps application by using catches and fuel consumption indicators. The results from this
54 research can be considered to replace the traditional CFL lamps with LED fishing lamps that
55 was more efficient and environmental friendly to promote sustainable fisheries at Bagan
56 fishing in Banten Bay Indonesia.

57

58 **2. Material and methods**

59 Lift net fishing in Banten Bay used varies CFL lamps with ranged of output power
60 between 24 W to 90 W per unit. In this research, we tried to introduce the new LED lamps
61 and analysed the effectiveness of both lamps based on catch weight and fuel consumption.
62 Light sources in this experiment are white LED lamps (Fujilight bulb 30 W, 2500 lumens)
63 and white CFL lamps (Cahaya 4U model 90 W, 2400 lumens). These lamps were chosen
64 based on several reasons. The CFL lamps are an existing light source that was used by local
65 fishermen because low price, easy to be obtained, and bright enough to attract fish schooling.
66 Meanwhile, LED lamps have very long operating life, small, low energy consumption (Shen
67 et al., 2012; Matsushita and Yamashita, 2012; Hua and Xing, 2013) and they have similar
68 lumens output with CFL lamps based on manufacture specification.

69 The CFL and LED lamps have different model and construction. They will affect to
70 difference of light distribution of both lamps. To analyse the pattern of light distribution, we
71 investigated the illuminance of both lamps in air and bottom of the sea water. Measurements
72 of luminous intensity in air were performed in dark room at Fisheries Department Laboratory
73 Sultan Ageng Tirtayasa University using digital lux meter (Lutron model LX-103 min scale 1

74 lx). The light intensity distributions were investigated by rotating sensor at every 10-degree
75 with radius 1 m from the light source to the sensor (Wisudo et al., 2002).

76 Fishing operation was conducted at 2 fixed lift net in Banten Bay with coordinate of LED
77 and CFL lamps at 05°58'02"S; 106°09'40"E and 05°58'05"S; 106°09'58"E, respectively. The
78 platform size of both bagan was 14 m length, 14 m breadth and 12 m depth. Its box-shaped
79 net was 12 m length and 12 m breadth, with 3 mm mesh size of polyamide. Light illuminance
80 of LED and CFL lamps at night in sea water was measured by underwater lux meter (LUW
81 1000D) at sea surface to 10 m depth during fishing operation. The measurements were
82 conducted at the centre, middle and corner of platform with 1 m interval (Figure 1).

83 The first lift net used 6 units of CFL (each lamps is 90 W) and the second bagan used 6
84 unit LED (each lamps is 30 W) to attract fish schooling into catchable area. The fishing
85 operations were conducted from 7:00 PM to 05:00 AM and the lamps were turned on between
86 2-4 hours every setting process. The catch data were recorded soon after hauling by sorting
87 the fish based on species, and then weight measured for each species. Fuel consumption of
88 gasoline generator was investigated by adding new fuel using measuring glass every morning
89 after finishing the fishing operation.

90 Light distribution of LED and CFL lamp in air presented and compared graphically as
91 radar diagram. Luminous intensity of both lamps in sea water shown as graphic of light
92 intensity distribution pattern and describe descriptively. Catch weight (kg) and fuel
93 consumption (l) data were evaluated graphically and performed by *t*-test analysis ($\alpha = 0.05$).
94 The graphical comparisons of catch weight combined across with fishing trip using total
95 catch, main catch and proportion of main catch that expressed as a percentage of main catch.

96

97

98 **3. Results**

99 Distribution pattern of luminous intensity (lux) of the CFL and LED lamps in the air
100 shows in Figure 2. The light distributions of CFL lamp have main area around the left and
101 right side. Meanwhile the LED lamp has majority of illumination on the bottom of the bulb.
102 The maximum intensity of CFL and LED lamps are 775 lx and 783 lx respectively.

103 Light illuminances in sea water from CFL and LED lamps have different distribution as
104 shows in Figure 3. The LEDs have higher intensity in surface water until 5 m deep than CFLs,
105 but the both light source have similar characteristics at 5 to 10 m deep. Light distribution of
106 LED light is more effective and it has homogenous pattern on vertical and horizontal
107 direction. Meanwhile the CFLs are slightly different on vertical, especially on the centre of
108 lift net that have lower intensity than left and right side. The illumination zone for CFL lamps
109 is narrow than LED lamps and it will affect to catchable area on fish capture process.

110 A total of 120 operations were conducted on 20 days fishing trip by 2 lift net during 22
111 May-16 June 2015. There was no fishing trips around the full moon (1-5 June) and fixed lift
112 net located in shallow water of Banten Bay less than 15 m deep. The total catch from 2 lift net
113 is 616.57 kg (mean 15.41 ± 0.15 SD). The highest catches is 310.50 kg on lift net that using
114 CFL lamps. The daily catch of CFLs ranged from 6 to 39 kg (mean 15.53 ± 8.94 SD) and
115 LEDs have varied from 7 to 31 kg (mean 15.30 ± 6.10 SD). Figure 4 shows the daily catch
116 from each lift net during experiment. There are no significant different between the total catch
117 of CFL and LED lamps.

118 Anchovy (*Stolephorus* sp.) is an economic commodity that becomes main target species
119 of lift net fisheries. Figure 5 shows the daily catch of anchovy during experiment. There are a
120 significant different of catches between LEDs and CFLs on trip 1, 3, 5, 6, 8, 9, 11, 13, 17 and
121 20, respectively. Lift net with CFL lamps get high catches on trip 8, 10 and 19, meanwhile

122 LEDs have more catches on other fishing trip. The maximum catches of LEDs and CFLs were
123 15.4 kg (mean 9.82 ± 3.72 SD) and 14.0 kg (mean 8.09 ± 3.11 SD) respectively.

124 Catch composition during experiment shows the LEDs fixed lift net dominated by
125 *Stolephorus* sp (61.77%), *Sardinella fimbriata* (14.70%), *Leiognathus* sp (14.20%), *Terapon*
126 sp (3.96) and others species (5.29%). The CFLs catches also dominated by *Stolephorus* sp
127 (59.99%), followed by *Sardinella fimbriata* (22.60%), *Leiognathus* sp (8.18%), *Terapon* sp
128 (5.61) and others species (3.61%). Meanwhile there was no significant difference between
129 daily total catch of each lamp (p-value 0.2218). Figure 6 shows the proportion (%) of catches
130 weight of LED and CFL during fishing operation. There are slightly different of catches
131 between LED and CFL almost on every fishing trip. The application of LED lamps can get
132 25% to 90% of anchovy (mean 67 ± 21 SD), while CFL lamps produce 33% to 83% (mean $58 \pm$
133 14 SD). The field experiment of the LED lamps presented no technical problems, especially
134 for the maintenance and replacing the CFL lamps. Specifically, overall increase of main
135 catches using LED lamps of 29%.

136 The lift net fishing used gasoline generator as a main source of electric power. The
137 maximum output of the generator reaches 2,000 W. Duration for lighting in one day trip
138 approximately 10 hours (07:00 AM to 05:00 PM). Fuel consumption of CFL lamps is higher
139 than LED lamps as shows in Figure 7. Fishing operation using LED lamps consumed 3.30 to
140 5.30 l/night (mean 4.11 ± 0.61 SD), while CFL lamps consumed 5.20 to 7.00 l/night (mean
141 6.33 ± 0.54 SD). Fuel consumption rate (l/h) under various lamps showed different tendencies.
142 When all the lamps were turn on, lift net with LED lamps consumed 0.33-5.33 l/h for lighting
143 output 180 W and lift net with CFL lamps consumed 0.52-0.70 l/h against 560 W output.

144 Figure 8 shows the reduction of fuel consumption (%) on lift net operation using LED
145 lamps. Replacing CFL with LED lamps will decrease of fuel consumption during fishing
146 experiment. Reduction of fuel consumption ranged from 18% to 45% (mean 35.15 ± 7.76 SD).

147 The LED is an appropriate lamp technology for the lift net fisheries especially to reduce fuel
148 consumption and promote the environmental friendly of small scale fisheries in Banten Bay.

149

150 **4. Discussion**

151 The number of fixed lift net in Banten Bay on 2015 reaches 62 units and most of them
152 used CFL lamps to attract target fishes to the catchable area. Fishermen changed their
153 pressurized kerosene lanterns with CFL lamps since 2000 to increase the productivity of lift
154 net fishing operation. The fishers select appropriate CFL lamps based on practical and
155 economic reasons. In this case, low price, easy to used, easy to be obtained, and bright enough
156 are the main consideration that were underlie by local fishermen to select varies of CFL
157 lamps. Nevertheless, application of high output of CFL lamp (up to 90 W per unit) cause
158 increasing of gasoline fuel consumption during fishing operation.

159 It is evident from Figure 2 that LED produced high intensity at the bottom of lamps
160 (angle 0° - 40° and 320° - 360°). Meanwhile the CFL transmitted high intensity at both side of
161 lamps (angle 60° - 100° and 260° - 310°). There are significant different of light distribution
162 because each lamps have different shape and constructions. The CFL lamp has more surface
163 area at the side (u-tube construction), so these sections have maximum light distribution.
164 Light emitted from the bottom of CFL comes from the bottom side of u-tube that had limited
165 surface area and causes the decreasing of light intensity from the lamp (Puspito et al., 2015).
166 Moreover, light from LED lamp has straight direction especially to the bottom area. LED
167 light sources are highly directional and highly efficient light emitters that can focus the light
168 intensity (Shen et al., 2012). It causes maximum intensity at the bottom of lamps position.
169 The spectrum, intensity and light distribution of lamps have specific characteristics depends
170 on shape and purpose of lamps manufacture (Anongponyoskun et al., 2011).

171 Fishermen used iron lamp shade (350 mm diameter) to focus the light during fishing
172 operation. The characteristic of light sources cause different light distribution pattern in sea
173 water, even if it used same lamp shade. LED light distribution had deeper penetration and
174 widely expanded than CFL light. The maximum intensity of LEDs and CFLs at the sea water
175 surface was 2,244 lx and 758 lx respectively on the centre of lift net platform. There were
176 different pattern of iso-lux contour from each lamps at more than 2 m depth. LED light
177 presented U-shape and CFL light have W-shape that decreased with increasing of depth
178 water. It is related to lamps design, construction and light characteristics from each lamp.
179 Light from LED source have sharp distribution and arrives enough at 15 m depth and have no
180 extreme change in spectrum from the surface to 15 m depth sea water (Okamoto et al., 2008).
181 In this research, lift net fishing operation used the general lighting of LED and CFL lamps
182 that was not designed specifically as fishing lamps. Moreover, the light intensity decrease
183 rapidly related to the emergence angle and its distribution varied at target plane. The lens of
184 LED source with novel design using double freeform surface is an effective method to
185 improve uniformity of light illuminance from 67.20% to 86.43% (Wu et al., 2015).

186 The light illuminance and distribution from both lamps around fixed lift net platform
187 have similar effectiveness to attract fish into catchable area. Mean catch per unit effort in
188 squid jigging fishery using only 216 LED lamps lower than using 78 Metal Halide Lamps,
189 because LED lamps irradiated only a limited area near of vessel (Shikata et al., 2012). Catch
190 weight of boat lift net using flood LED lamps also lower than mercury lamps (Sulaiman et al.,
191 2015). It was indicated the general lighting of LED lamp cannot used directly as effective
192 fishing lamp on capture fisheries. Fish behaviour and response related to light emitted of LED
193 were investigated to improve design and to obtain an appropriate specification of the new
194 generation of fishing lamps in fishing activities (Mills et al., 2014). The new design of white
195 LED lamps used multi-segmented freeform lens (MSFL) can perform better as fishing lamps,

196 3 times more efficient, than the traditional High Intensity Discharge (HID) lamp (Lai et al.,
197 2015).

198 The anchovy as main target species of fixed lift net in Banten Bay has high economic
199 value (Indonesia Rupiah/IDR 75,000 – 90,000 per kg/United State Dollar/USD 5.77-6.92 per
200 kg). LED lamps application in this experiment had significant effect to catch weight of
201 anchovy (p-value 0.0087). It is evident from Figure 5 and 6 that catches weight and
202 proportion of main catch using LED lamps is higher than CFL lamps. Previous researches
203 show varied result of LED performance in fishing operation. Combination of LED panel with
204 24 metal halide lamps presented highest catch of Japanese common squid (Yamashita et al.
205 2012). Light from white LED lamp could penetrate to deeper water and caught more white
206 anchovy (*Stolephorus indicus*) than mercury lamps (Sulaiman et al., 2015a). Blue LED was
207 recommended to gathering the squid and white LED was very useful to squid fishing (Jeong
208 et al., 2013). Fishing experiment using LED and metal halide lamp in Korean squid jigging
209 fisheries presented that catches of squids per the fishing vessel with 1 W LED fishing lamp
210 were higher up to 135.5% than the fishing vessel with metal halide (An, 2014). Main catch
211 (*Stolephorus* sp.) per unit energy of boat lift net in Sulawesi using LED and mercury lamp is
212 11.61 kg/W and 3.77 kg/W respectively (Sulaiman et al., 2015b).

213 White LED in this research have dominant wavelength at 450 nm and 590 nm. It is
214 similar properties with Bae et al. (2011) that used the dominant wavelength of white LED at
215 450 nm and 550 nm to attract *Engraulis japonicus*. Characteristic of fishing lamps will have
216 affected to catch weight and species composition. It is related to behaviour and response of
217 fish to light attractant. Each species has different maximum absorbance of light spectrum
218 depend on structure and morphology of retinae. *Stolephorus indicus* have poly-cone type with
219 cone density $684 \times 10^4 \mu\text{m}^2$. It is indicate that retinae of this species very adapted to light
220 stimulant (Heb et al., 2006). *Engraulis japonicus* and *Engraulis encrasicolus* have triple cone

221 with maximum absorbance wavelength approximately at 502 nm, while the short central
222 components were more shortwave sensitive ($\alpha_{\max} = 475$ nm). The α_{\max} of all long and short
223 cones in the ventro-temporal zone was 492 nm, compared to 502 nm in other retinal regions
224 (Kondrashev et al., 2012). The dominant catch of *Stolephorus* sp. during experiment indicated
225 the transmitted wavelengths from LED lamps were appropriate enough to the maximum
226 absorbance of anchovy. It schooling influenced, gathering and stay into catchable area for the
227 long times as a response of light adaptation behaviour.

228 LED lamps had lower fuel consumption than CFL during fishing operation. It is evident
229 from Figure 7 and 8 that LED is efficient light source with mean saving energy up to 35%.
230 Application LED lamps in fixed lift net in Banten Bay had significant effect to reduce fuel
231 consumption (p-value 5.01×10^{-14}). LED fishing lamps in hair-tail angling at Korean fisheries
232 had higher fishing performance, save 33% of fuel consumption, decreased the operation
233 expenses and green house emission (An et al., 2012). Fishing experiment at purse seine and
234 squid jigging fisheries showed LED lamps have high productivity and lower fuel consumption
235 than metal halide lamps. LED lamps save 50% of fuel than metal halide (Hua and Xing 2013),
236 more efficient up to 80% than high intensity discharge (Shen et al., 2012) and save 24% of
237 fuel in Japanese squid jigging fisheries (Matshushita et al., 2012). Application LED lamps in
238 Korean squid jigging industries also decreased 65,163 kl of fuel consumption in a year (Park
239 et al., 2015). In small scale fisheries, replacing CFL lamps with LED lamps save 37.5% of
240 fuel consumption in fixed lift net at Lesung Cape Banten Province (Arif et al., 2015).

241 In conclusions, we found the light distribution of commercial LED lamps could penetrate
242 wider and deeper to the catchable area than CFL lamps and were good enough to attract the
243 target species of anchovy. Application of LED lamps had significant effect to the catch
244 weight of anchovy and save fuel consumption. The LED lamps are the potential suitable light
245 source for replacing CFL lamps and developing sustainable lift net fisheries in Banten Bay.

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250

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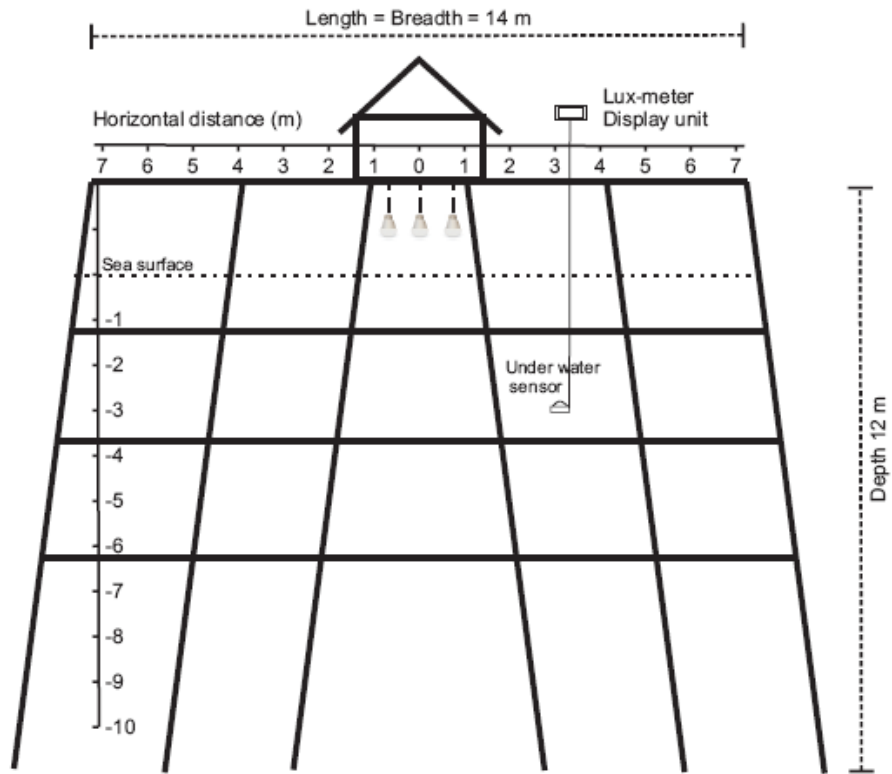
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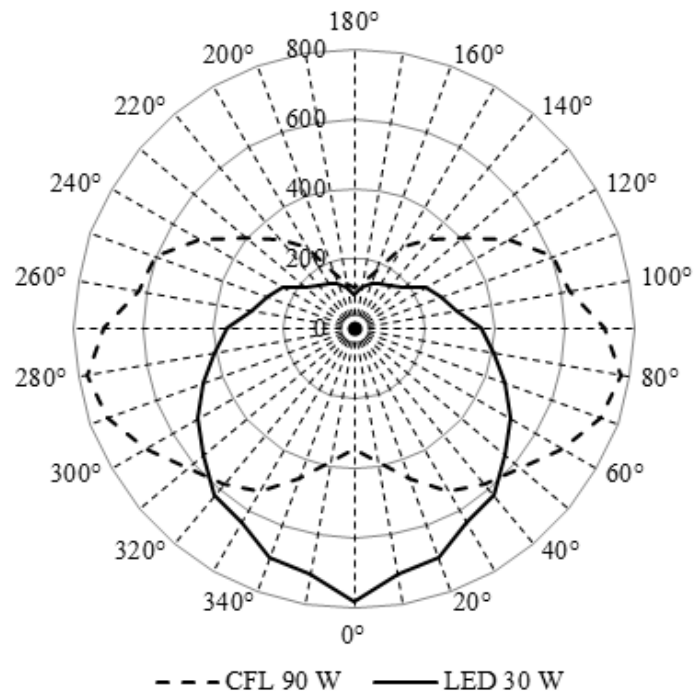
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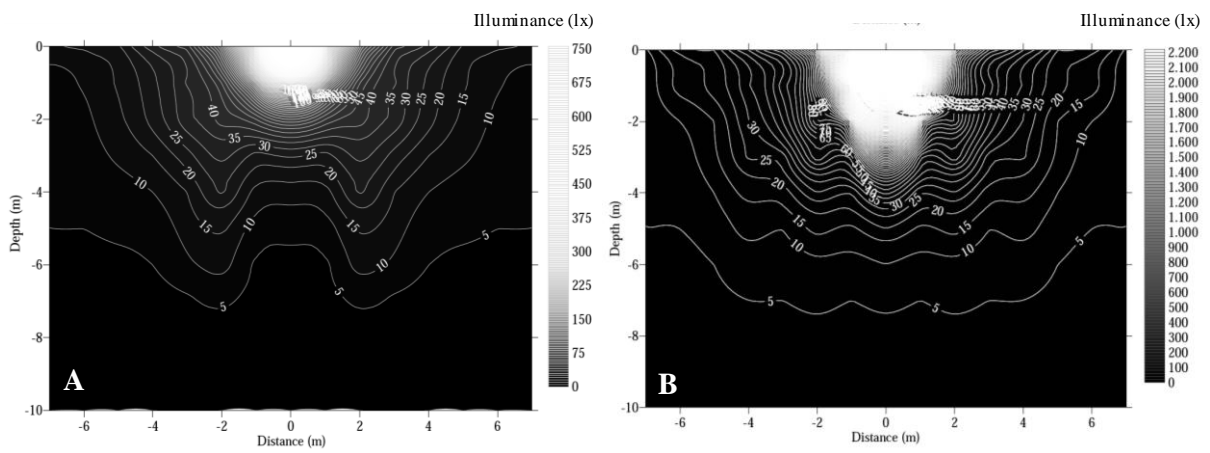
Figure 1. The arrangement of light intensity measurement in sea water.



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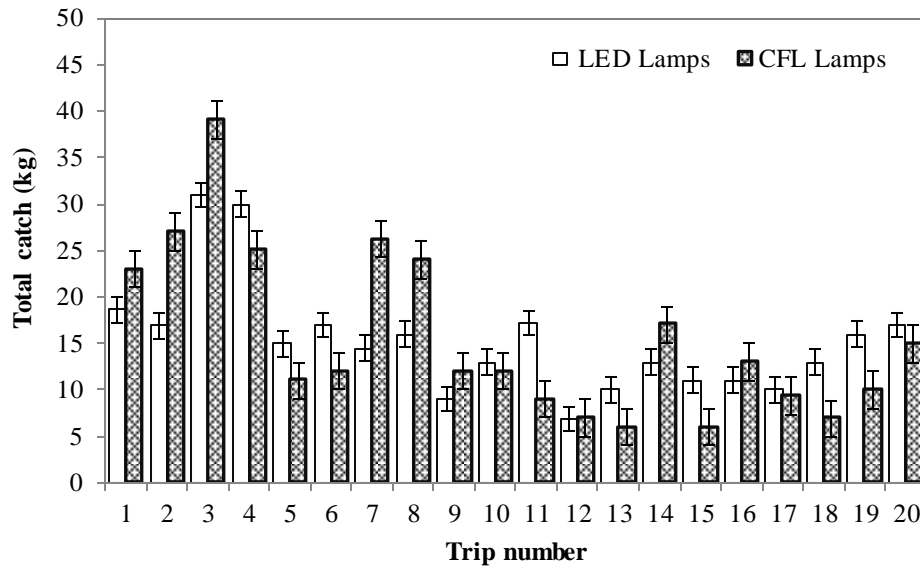
Figure 2. Distribution of light intensity of CFL and LED lamps in the air.



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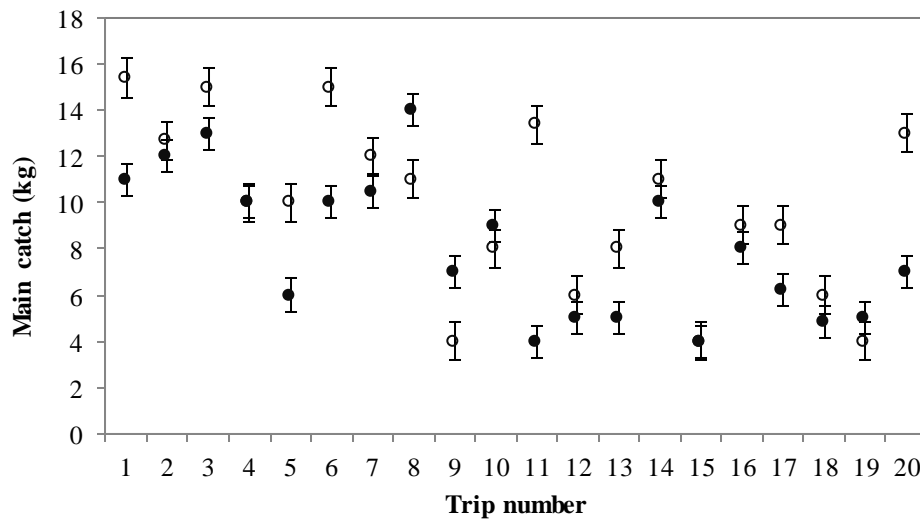
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Figure 3. Sea water light distribution of CFL (A) and LED (B) lamps.



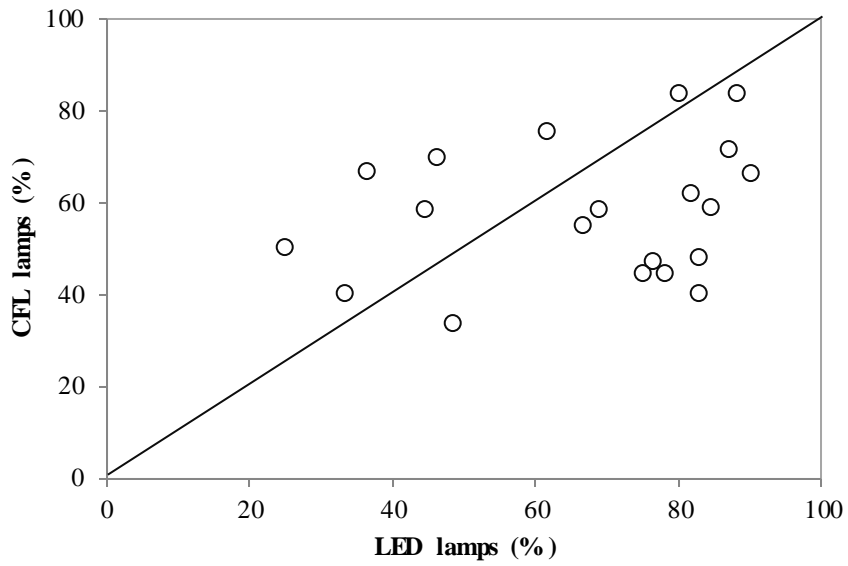
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378 Figure 4. Daily catch of CFLs and LEDs lamps (Vertical lines denote standard errors).



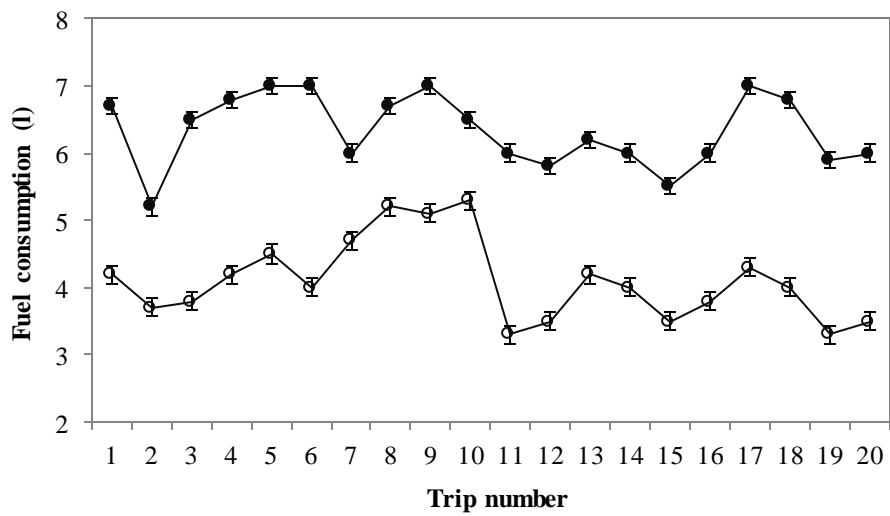
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380 Figure 5. Daily main catches of lift net with LED (circle) and CFL (point) (Vertical lines
 381 denote standard errors).



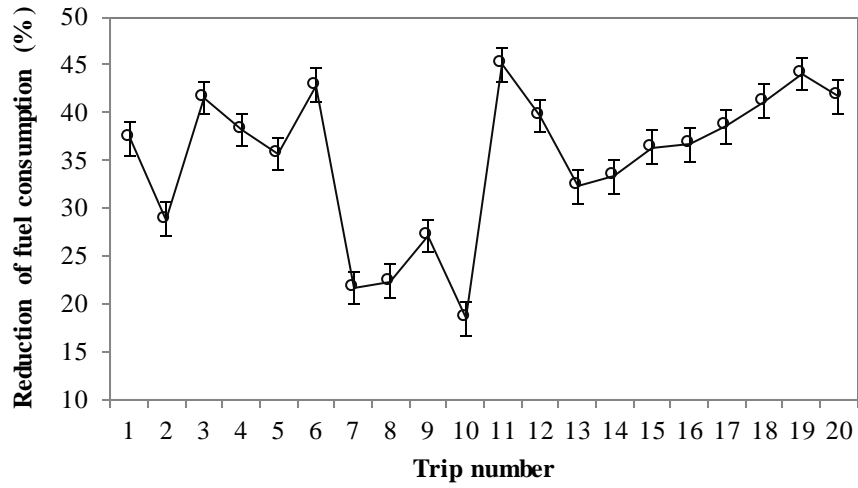
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383 Figure 6. Proportion (%) of lift net main catches using LED lamps plotted against CFL lamps.



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385 Figure 7. Fuel consumption of lift net using LED (circle) and CFL (point) (Vertical lines
386 denote standard errors).



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388 Figure 8. Reduction of fuel consumption of fixed lift net using LED lamps (Vertical lines

389 denote standard errors).

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Main
Document

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Abstract

1
2 Fixed lift net fisheries in Banten Bay used compact fluorescent lamp (CFL) since the
3 middle of 2000 for replacement the traditional pressured kerosene lantern. It was increased
4 the light intensity, but this lamps consumed high energy and fuels. Application of light
5 emitting diode (LED) is considered to energy saving and increased catches in lift net fisheries.
6 The fishing trial was conducted on 22 May-16 June 2015 in Banten Bay Indonesia using 2
7 units of lift net with 6 units of CFL and LED respectively. The result shows both lamps did
8 not have significant effect on total catches. Meanwhile, application of LED lamps has
9 significant effect to main catch that anchovy. There were increasing catch weight of anchovy
10 with mean 29.49%. LED also decreased of fuel consumption with mean saving 35.15%. It is
11 evident enough to conclude that LED lamps have high efficiency and effectiveness for lift net
12 fishing in Banten Bay.

13 Key word: anchovy, compact fluorescent lamp, light fishing, fuel consumption

14

15 1. Introduction

16 Fishing with light is a successful of modern fishing technique that was used in Indonesia
17 since 1950 in various fishing gears (Ben-Yami 1976). The light fishing gears in Indonesia
18 dominated by lift net (bagan) and purse seine (Sudirman and Musbir, 2009). There are 2 types
19 of bagan in Banten Bay Indonesia, fixed lift net as the small scale fisheries, and boat lift net as
20 the thrive of light fishing activities. Bagan has used compact fluorescent lamp (CFL) as
21 fishing lamps to attract photo taxis positive of fish schooling since 15 years ago. It replaced
22 pressurized kerosene lanterns that were used by fishers before developing of gasoline
23 generator as the electric power source. There are variety of light power (W), number of light
24 units, and manufacture of CFL lamps used on bagan fisheries based on traditional knowledge
25 and fishermen experience.

1 Fishing lamp is a key component for light fishing activities. The light sources of fishing
2 lamps have developed from torch, acetylene, kerosene, incandescent, mercury, fluorescent,
3 and halogen lamps to the metal halide (MH) lamps (Inada and Arimoto, 2007; Ben-Yami,
4 1976). Fishermen generally think that the catch of light fishing will increase with the rises of
5 light power. However, there are many factors that affect fish attraction such as the quality of
6 light (e.g. wavelength), quantity of light (e.g. power), and arrangement of fishing lights. In
7 addition, underwater illuminance, irradiance level and distribution created by these factors are
8 influenced by the optical characteristics of seawater and influence to the fish behaviour
9 (Arakawa et al., 1998; Shikata et al., 2011).

10 The scientific basis evident for selecting the appropriate of light source and its power as
11 fishing lamps still remains unverified. Information about the relationship between fishing
12 lights and fish behavior is still limited and consequently fishermen determine the type,
13 number and power of fishing lights based on their personal experience (Yamashita et al.,
14 2012). Meanwhile, light source in fishing attraction by light, which mainly includes filament
15 lamp, halogen tungsten lamp, mercury and metal halide, all belongs to thermal light source
16 (Hua and Xing, 2013). The light from these lamps is omnidirectional and, therefore, most of it
17 does not reach the target areas, such as the deck and the surrounding water (Lai et al., 2015).
18 Although these sources have improved light intensity, their main handicap is that these lamps
19 consumed a great amount of electric energy and fuel (Kehayias et al., 2016).

20 Compared with these conventional lamps, LED (light emitting diode) have many
21 advantages, such as high efficiency, a long lifetime, fast response and together with climate
22 resistance (Lai et al., 2015). Furthermore, LEDs, which do not contain mercury (as opposed to
23 CFL), are tolerant of low voltages, very small and portable, and have high optical efficiency.
24 LEDs are often submersible, and it can be compared favourably, technically and economically

1 with all other forms of lighting for small-scale applications (McHenry et al., 2014). Thus,
2 LEDs have been considered the most promising new lighting solution for a fishing fleet.

3 The objective of this research is to compare and to analyse the effectiveness of LED
4 lamps application by using catches and fuel consumption indicators. The results from this
5 research can be considered to replace the traditional CFL lamps with LED fishing lamps that
6 was more efficient and environmental friendly to promote sustainable fisheries at Bagan
7 fishing in Banten Bay Indonesia.

8

9 **2. Material and methods**

10 Lift net fishing in Banten Bay used varies CFL lamps with ranged of output power
11 between 24 W to 90 W per unit. In this research, we tried to introduce the new LED lamps
12 and analysed the effectiveness of both lamps based on catch weight and fuel consumption.
13 Light sources in this experiment are white LED lamps (Fujilight bulb 30 W, 2500 lumens)
14 and white CFL lamps (Cahaya 4U model 90 W, 2400 lumens). These lamps were chosen
15 based on several reasons. The CFL lamps are an existing light source that was used by local
16 fishermen because low price, easy to be obtained, and bright enough to attract fish schooling.
17 Meanwhile, LED lamps have very long operating life, small, low energy consumption (Shen
18 et al., 2012; Matsushita and Yamashita, 2012; Hua and Xing, 2013) and they have similar
19 lumens output with CFL lamps based on manufacture specification.

20 The CFL and LED lamps have different model and construction. They will affect to
21 difference of light distribution of both lamps. To analyse the pattern of light distribution, we
22 investigated the illuminance of both lamps in air and bottom of the sea water. Measurements
23 of luminous intensity in air were performed in dark room at Fisheries Department Laboratory
24 Sultan Ageng Tirtayasa University using digital lux meter (Lutron model LX-103 min scale 1

Comment [x1]: Input power/output power?
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1 lx). The light intensity distributions were investigated by rotating sensor at every 10-degree
2 with radius 1 m from the light source to the sensor (Wisudo et al., 2002).

3 Fishing operation was conducted at 2 fixed lift net in Banten Bay with coordinate of LED
4 and CFL lamps at 05°58'02"S; 106°09'40"E and 05°58'05"S; 106°09'58"E, respectively. The
5 platform size of both bagan was 14 m length, 14 m breadth and 12 m depth. Its box-shaped
6 net was 12 m length and 12 m breadth, with 3 mm mesh size of polyamide. Light illuminance
7 of LED and CFL lamps at night in sea water was measured by underwater lux meter (LUW
8 1000D) at sea surface to 10 m depth during fishing operation. The measurements were
9 conducted at the centre, middle and corner of platform with 1 m interval (Figure 1).

10 The first lift net used 6 units of CFL (each lamps is 90 W) and the second bagan used 6
11 unit LED (each lamps is 30 W) to attract fish schooling into catchable area. The fishing
12 operations were conducted from 7:00 PM to 05:00 AM and the lamps were turned on between
13 2-4 hours every setting process. The catch data were recorded soon after hauling by sorting
14 the fish based on species, and then weight measured for each species. Fuel consumption of
15 gasoline generator was investigated by adding new fuel using measuring glass every morning
16 after finishing the fishing operation.

17 Light distribution of LED and CFL lamp in air presented and compared graphically as
18 radar diagram. Luminous intensity of both lamps in sea water shown as graphic of light
19 intensity distribution pattern and describe descriptively. Catch weight (kg) and fuel
20 consumption (l) data were evaluated graphically and performed by *t*-test analysis ($\alpha = 0.05$).
21 The graphical comparisons of catch weight combined across with fishing trip using total
22 catch, main catch and proportion of main catch that expressed as a percentage of main catch.

23

24

Comment [x2]: Is it correct? Only 1 mm.

1 **3. Results**

2 Distribution pattern of luminous intensity (lux) of the CFL and LED lamps in the air
3 shows in Figure 2. The light distributions of CFL lamp have main area around the left and
4 right side. Meanwhile the LED lamp has majority of illumination on the bottom of the bulb.
5 The maximum intensity of CFL and LED lamps are 775 lx and 783 lx respectively.

6 Light illuminances in sea water from CFL and LED lamps have different distribution as
7 shows in Figure 3. The LEDs have higher intensity in surface water until 5 m deep than CFLs,
8 but the both light source have similar characteristics at 5 to 10 m deep. Light distribution of
9 LED light is more effective and it has homogenous pattern on vertical and horizontal
10 direction. Meanwhile the CFLs are slightly different on vertical, especially on the centre of
11 lift net that have lower intensity than left and right side. The illumination zone for CFL lamps
12 is narrow than LED lamps and it will affect to catchable area on fish capture process.

13 A total of 120 operations were conducted on 20 days fishing trip by 2 lift net during 22
14 May-16 June 2015. There was no fishing trips around the full moon (1-5 June) and fixed lift
15 net located in shallow water of Banten Bay less than 15 m deep. The total catch from 2 lift net
16 is 616.57 kg (mean 15.41 ± 0.15 SD). The highest catches is 310.50 kg on lift net that using
17 CFL lamps. The daily catch of CFLs ranged from 6 to 39 kg (mean 15.53 ± 8.94 SD) and
18 LEDs have varied from 7 to 31 kg (mean 15.30 ± 6.10 SD). Figure 4 shows the daily catch
19 from each lift net during experiment. There are no significant different between the total catch
20 of CFL and LED lamps.

21 Anchovy (*Stolephorus* sp.) is an economic commodity that becomes main target species
22 of lift net fisheries. Figure 5 shows the daily catch of anchovy during experiment. There are a
23 significant different of catches between LEDs and CFLs on trip 1, 3, 5, 6, 8, 9, 11, 13, 17 and
24 20, respectively. Lift net with CFL lamps get high catches on trip 8, 10 and 19, meanwhile

1 LEDs have more catches on other fishing trip. The maximum catches of LEDs and CFLs were
2 15.4 kg (mean 9.82 ± 3.72 SD) and 14.0 kg (mean 8.09 ± 3.11 SD) respectively.

3 Catch composition during experiment shows the LEDs fixed lift net dominated by
4 *Stolephorus* sp (61.77%), *Sardinella fimbriata* (14.70%), *Leiognathus* sp (14.20%), *Terapon*
5 sp (3.96) and others species (5.29%). The CFLs catches also dominated by *Stolephorus* sp
6 (59.99%), followed by *Sardinella fimbriata* (22.60%), *Leiognathus* sp (8.18%), *Terapon* sp
7 (5.61) and others species (3.61%). Meanwhile there was no significant difference between
8 daily total catch of each lamp (p-value 0.2218). Figure 6 shows the proportion (%) of catches
9 weight of LED and CFL during fishing operation. There are slightly different of catches
10 between LED and CFL almost on every fishing trip. The application of LED lamps can get
11 25% to 90% of anchovy (mean 67 ± 21 SD), while CFL lamps produce 33% to 83% (mean $58 \pm$
12 14 SD). The field experiment of the LED lamps presented no technical problems, especially
13 for the maintenance and replacing the CFL lamps. Specifically, overall increase of main
14 catches using LED lamps of 29%.

15 The lift net fishing used gasoline generator as a main source of electric power. The
16 maximum output of the generator reaches 2,000 W. Duration for lighting in one day trip
17 approximately 10 hours (07:00 AM to 05:00 PM). Fuel consumption of CFL lamps is higher
18 than LED lamps as shows in Figure 7. Fishing operation using LED lamps consumed 3.30 to
19 5.30 l/night (mean 4.11 ± 0.61 SD), while CFL lamps consumed 5.20 to 7.00 l/night (mean
20 6.33 ± 0.54 SD). Fuel consumption rate (l/h) under various lamps showed different tendencies.
21 When all the lamps were turn on, lift net with LED lamps consumed 0.33-5.33 l/h for lighting
22 output 180 W and lift net with CFL lamps consumed 0.52-0.70 l/h against 560 W output.

23 Figure 8 shows the reduction of fuel consumption (%) on lift net operation using LED
24 lamps. Replacing CFL with LED lamps will decrease of fuel consumption during fishing
25 experiment. Reduction of fuel consumption ranged from 18% to 45% (mean 35.15 ± 7.76 SD).

1 The LED is an appropriate lamp technology for the lift net fisheries especially to reduce fuel
2 consumption and promote the environmental friendly of small scale fisheries in Banten Bay.

3

4 **4. Discussion**

5 The number of fixed lift net in Banten Bay on 2015 reaches 62 units and most of them
6 used CFL lamps to attract target fishes to the catchable area. Fishermen changed their
7 pressurized kerosene lanterns with CFL lamps since 2000 to increase the productivity of lift
8 net fishing operation. The fishers select appropriate CFL lamps based on practical and
9 economic reasons. In this case, low price, easy to used, easy to be obtained, and bright enough
10 are the main consideration that were underlie by local fishermen to select varies of CFL
11 lamps. Nevertheless, application of high output of CFL lamp (up to 90 W per unit) cause
12 increasing of gasoline fuel consumption during fishing operation.

13 It is evident from Figure 2 that LED produced high intensity at the bottom of lamps
14 (angle 0° - 40° and 320° - 360°). Meanwhile the CFL transmitted high intensity at both side of
15 lamps (angle 60° - 100° and 260° - 310°). There are significant different of light distribution
16 because each lamps have different shape and constructions. The CFL lamp has more surface
17 area at the side (u-tube construction), so these sections have maximum light distribution.
18 Light emitted from the bottom of CFL comes from the bottom side of u-tube that had limited
19 surface area and causes the decreasing of light intensity from the lamp (Puspito et al., 2015).
20 Moreover, light from LED lamp has straight direction especially to the bottom area. LED
21 light sources are highly directional and highly efficient light emitters that can focus the light
22 intensity (Shen et al., 2012). It causes maximum intensity at the bottom of lamps position.
23 The spectrum, intensity and light distribution of lamps have specific characteristics depends
24 on shape and purpose of lamps manufacture (Anongponyoskun et al., 2011).

1 Fishermen used iron lamp shade (350 mm diameter) to focus the light during fishing
2 operation. The characteristic of light sources cause different light distribution pattern in sea
3 water, even if it used same lamp shade. LED light distribution had deeper penetration and
4 widely expanded than CFL light. The maximum intensity of LEDs and CFLs at the sea water
5 surface was 2,244 lx and 758 lx respectively on the centre of lift net platform. There were
6 different pattern of iso-lux contour from each lamps at more than 2 m depth. LED light
7 presented U-shape and CFL light have W-shape that decreased with increasing of depth
8 water. It is related to lamps design, construction and light characteristics from each lamp.
9 Light from LED source have sharp distribution and arrives enough at 15 m depth and have no
10 extreme change in spectrum from the surface to 15 m depth sea water (Okamoto et al., 2008).
11 In this research, lift net fishing operation used the general lighting of LED and CFL lamps
12 that was not designed specifically as fishing lamps. Moreover, the light intensity decrease
13 rapidly related to the emergence angle and its distribution varied at target plane. The lens of
14 LED source with novel design using double freeform surface is an effective method to
15 improve uniformity of light illuminance from 67.20% to 86.43% (Wu et al., 2015).

16 The light illuminance and distribution from both lamps around fixed lift net platform
17 have similar effectiveness to attract fish into catchable area. Mean catch per unit effort in
18 squid jigging fishery using only 216 LED lamps lower than using 78 Metal Halide Lamps,
19 because LED lamps irradiated only a limited area near of vessel (Shikata et al., 2012). Catch
20 weight of boat lift net using flood LED lamps also lower than mercury lamps (Sulaiman et al.,
21 2015). It was indicated the general lighting of LED lamp cannot used directly as effective
22 fishing lamp on capture fisheries. Fish behaviour and response related to light emitted of LED
23 were investigated to improve design and to obtain an appropriate specification of the new
24 generation of fishing lamps in fishing activities (Mills et al., 2014). The new design of white
25 LED lamps used multi-segmented freeform lens (MSFL) can perform better as fishing lamps,

1 3 times more efficient, than the traditional High Intensity Discharge (HID) lamp (Lai et al.,
2 2015).

3 The anchovy as main target species of fixed lift net in Banten Bay has high economic
4 value (Indonesia Rupiah/IDR 75,000 – 90,000 per kg/United State Dollar/USD 5.77-6.92 per
5 kg). LED lamps application in this experiment had significant effect to catch weight of
6 anchovy (p-value 0.0087). It is evident from Figure 5 and 6 that catches weight and
7 proportion of main catch using LED lamps is higher than CFL lamps. Previous researches
8 show varied result of LED performance in fishing operation. Combination of LED panel with
9 24 metal halide lamps presented highest catch of Japanese common squid (Yamashita et al.
10 2012). Light from white LED lamp could penetrate to deeper water and caught more white
11 anchovy (*Stolephorus indicus*) than mercury lamps (Sulaiman et al., 2015a). Blue LED was
12 recommended to gathering the squid and white LED was very useful to squid fishing (Jeong
13 et al., 2013). Fishing experiment using LED and metal halide lamp in Korean squid jigging
14 fisheries presented that catches of squids per the fishing vessel with 1 W LED fishing lamp
15 were higher up to 135.5% than the fishing vessel with metal halide (An, 2014). Main catch
16 (*Stolephorus* sp.) per unit energy of boat lift net in Sulawesi using LED and mercury lamp is
17 11.61 kg/W and 3.77 kg/W respectively (Sulaiman et al., 2015b).

18 White LED in this research have dominant wavelength at 450 nm and 590 nm. It is
19 similar properties with Bae et al. (2011) that used the dominant wavelength of white LED at
20 450 nm and 550 nm to attract *Engraulis japonicus*. Characteristic of fishing lamps will have
21 affected to catch weight and species composition. It is related to behaviour and response of
22 fish to light attractant. Each species has different maximum absorbance of light spectrum
23 depend on structure and morphology of retinae. *Stolephorus indicus* have poly-cone type with
24 cone density $684 \times 10^4 \mu\text{m}^2$. It is indicate that retinae of this species very adapted to light
25 stimulant (Heb et al., 2006). *Engraulis japonicus* and *Engraulis encrasicolus* have triple cone

1 with maximum absorbance wavelength approximately at 502 nm, while the short central
2 components were more shortwave sensitive ($\alpha_{\max} = 475$ nm). The α_{\max} of all long and short
3 cones in the ventro-temporal zone was 492 nm, compared to 502 nm in other retinal regions
4 (Kondrashev et al., 2012). The dominant catch of *Stolephorus* sp. during experiment indicated
5 the transmitted wavelengths from LED lamps were appropriate enough to the maximum
6 absorbance of anchovy. It schooling influenced, gathering and stay into catchable area for the
7 long times as a response of light adaptation behaviour.

8 LED lamps had lower fuel consumption than CFL during fishing operation. It is evident
9 from Figure 7 and 8 that LED is efficient light source with mean saving energy up to 35%.
10 Application LED lamps in fixed lift net in Banten Bay had significant effect to reduce fuel
11 consumption (p-value 5.01×10^{-14}). LED fishing lamps in hair-tail angling at Korean fisheries
12 had higher fishing performance, save 33% of fuel consumption, decreased the operation
13 expenses and green house emission (An et al., 2012). Fishing experiment at purse seine and
14 squid jigging fisheries showed LED lamps have high productivity and lower fuel consumption
15 than metal halide lamps. LED lamps save 50% of fuel than metal halide (Hua and Xing 2013),
16 more efficient up to 80% than high intensity discharge (Shen et al., 2012) and save 24% of
17 fuel in Japanese squid jigging fisheries (Matshushita et al., 2012). Application LED lamps in
18 Korean squid jigging industries also decreased 65,163 kl of fuel consumption in a year (Park
19 et al., 2015). In small scale fisheries, replacing CFL lamps with LED lamps save 37.5% of
20 fuel consumption in fixed lift net at Lesung Cape Banten Province (Arif et al., 2015).

21 In conclusions, we found the light distribution of commercial LED lamps could penetrate
22 wider and deeper to the catchable area than CFL lamps and were good enough to attract the
23 target species of anchovy. Application of LED lamps had significant effect to the catch
24 weight of anchovy and save fuel consumption. The LED lamps are the potential suitable light
25 source for replacing CFL lamps and developing sustainable lift net fisheries in Banten Bay.

1

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5 experimental platform for their cooperation during fishing trials.

6

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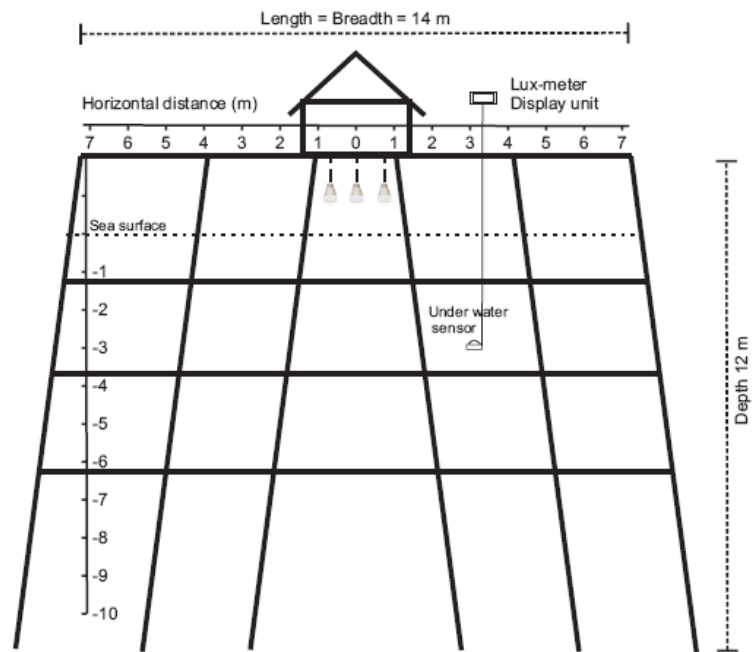
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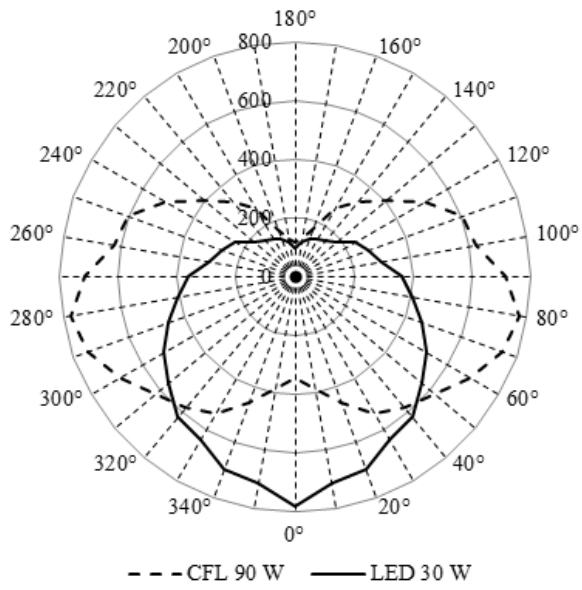
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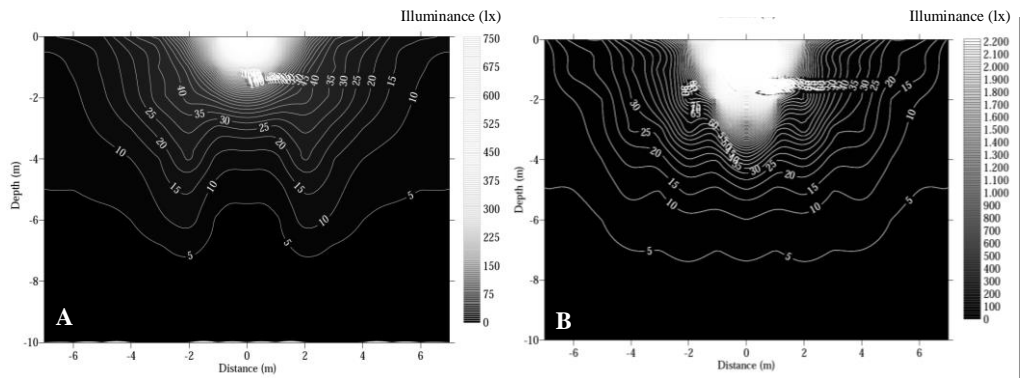
Figure 1. The arrangement of light intensity measurement in sea water.



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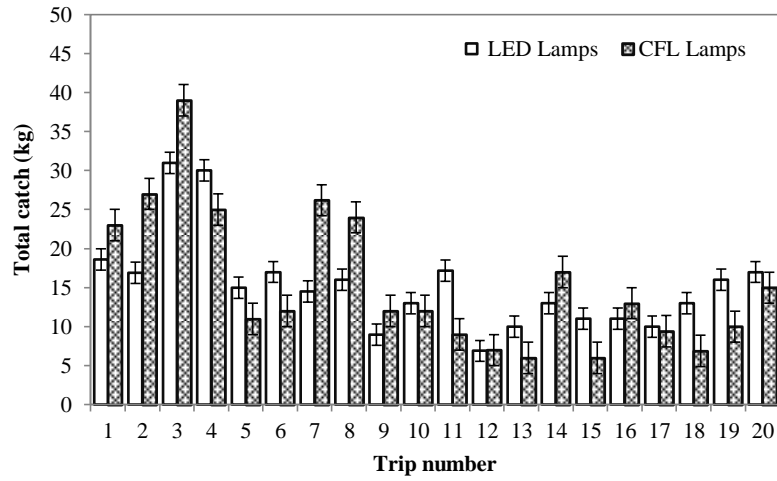
Figure 2. Distribution of light intensity of CFL and LED lamps in the air.



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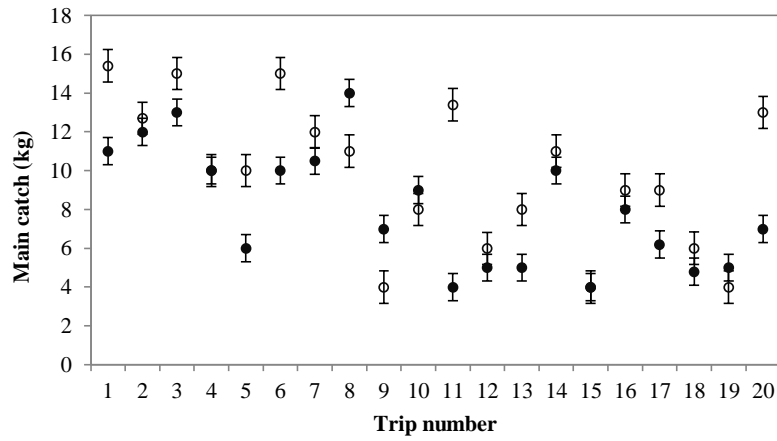
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Figure 3. Sea water light distribution of CFL (A) and LED (B) lamps.



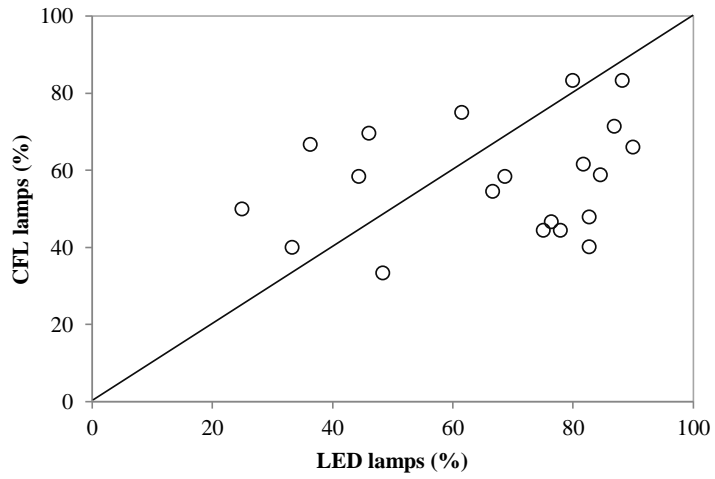
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2 Figure 4. Daily catch of CFLs and LEDs lamps (Vertical lines denote standard errors).



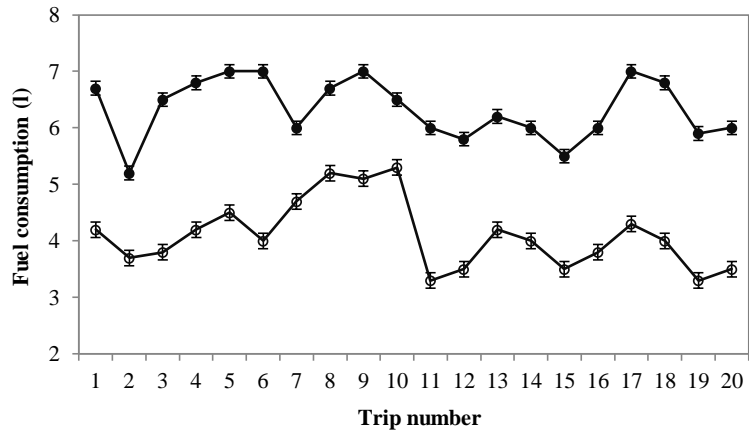
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4 Figure 5. Daily main catches of lift net with LED (circle) and CFL (point) (Vertical lines
5 denote standard errors).



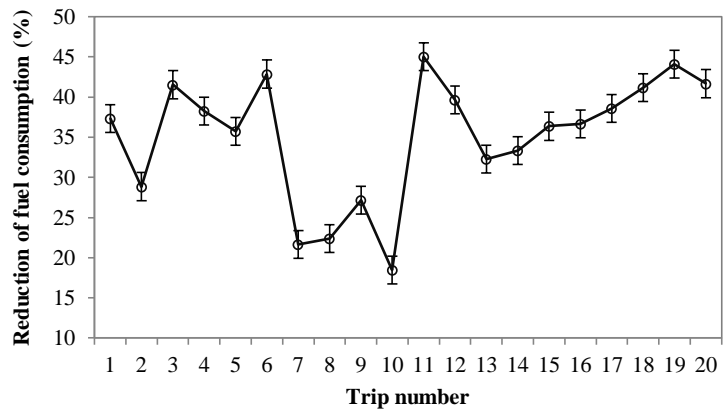
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2 Figure 6. Proportion (%) of lift net main catches using LED lamps plotted against CFL lamps.



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4 Figure 7. Fuel consumption of lift net using LED (circle) and CFL (point) (Vertical lines
5 denote standard errors).



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Figure 8. Reduction of fuel consumption of fixed lift net using LED lamps (Vertical lines denote standard errors).



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Keywords: anchovy, compact fluorescent lamp, light fishing, fuel consumption

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Abstract

Fixed lift net fisheries in Banten Bay used compact fluorescent lamp (CFL) since the middle of 2000 for replacement the traditional pressured kerosene lantern. It was increased the light intensity, but this lamps consumed high energy and fuels. Application of light emitting diode (LED) is considered to energy saving and increased catches in lift net fisheries. The fishing trial was conducted on 22 May-16 June 2015 in Banten Bay Indonesia using 2 units of lift net with 6 units of CFL and LED respectively. The result shows both lamps did not have significant effect on total catches. Meanwhile, application of LED lamps has significant effect to main catch that anchovy. There were increasing catch weight of anchovy with mean 29.49%. LED also decreased of fuel consumption with mean saving 35.15%. It is evident enough to conclude that LED lamps have high efficiency and effectiveness for lift net fishing in Banten Bay.

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TRJFAS-3157-3-main-document.pdf (../pdf-files/out/3698-TRJFAS-3157-3-main-document.pdf)	1010 KB	Jul 27, 2016	Main Document	Include Figure
TRJFAS-3157-3-figure.pdf (../pdf-files/out/3698-TRJFAS-3157-3-figure.pdf)	983 KB	Jul 21, 2016	Figure	None
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Fishing Efficiency of LED Lamps for Fixed Lift Net Fisheries in Banten Bay Indonesia

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Abstract

Fixed lift net fisheries in Banten Bay used compact fluorescent lamp (CFL) since the middle of 2000 for replacement the traditional pressured kerosene lantern. It was increased the light intensity, but this lamps consumed high energy and fuels. Application of light emitting diode (LED) is considered to energy saving and increased catches in lift net fisheries. The fishing trial was conducted on 22 May-16 June 2015 in Banten Bay Indonesia using 2 units of lift net with 6 units of CFL and LED respectively. The result shows both lamps did not have significant effect on total catches. Meanwhile, application of LED lamps has significant effect to main catch (anchovy). There were increasing catch weight of anchovy with mean 29.49%. LED also decreased of fuel consumption with mean saving 35.15%. It is evident enough to conclude that LED lamps have high efficiency and effectiveness for lift net fishing in Banten Bay.

Keywords: Anchovy, compact fluorescent lamp, light fishing, fuel consumption

Introduction

Fishing with light is a successful of modern fishing technique that was used in Indonesia since 1950 in various fishing gears (Ben-Yami 1976). The light fishing gears in Indonesia dominated by lift net (bagan) and purse seine (Sudirman and Musbir, 2009). There are 2 types of bagan in Banten Bay Indonesia, fixed lift net as the small scale fisheries, and boat lift net as the thrive of light fishing activities. Bagan has used compact fluorescent lamp (CFL) as fishing lamps to attract photo taxis positive of fish schooling since 15 years ago. It replaced pressurized kerosene lanterns that were used by fishers before developing of gasoline generator as the electric power source. There are variety of light power (W), number of light units, and manufacture of CFL lamps used on bagan fisheries based on traditional knowledge and fishermen experience.

Fishing lamp is a key component for light fishing activities. The light sources of fishing lamps have developed from torch, acetylene, kerosene, incandescent, mercury, fluorescent, and halogen lamps to the metal halide (MH) lamps (Inada and Arimoto, 2007; Ben-Yami, 1976). Fishermen generally think that the catch of light fishing will increase with the rises of light power. However, there are many factors that affect fish attraction such as the quality of light (e.g. wavelength), quantity of light (e.g. power), and arrangement of fishing lights. In addition, underwater illuminance, irradiance level and distribution created by these factors are influenced by the optical characteristics of seawater and influence to the fish behaviour (Arakawa et al., 1998; Shikata et al., 2011).



41 The scientific basis evident for selecting the appropriate of light source and its power as fishing lamps still
42 remains unverified. Information about the relationship between fishing lights and fish behavior is still limited
43 and consequently fishermen determine the type, number and power of fishing lights based on their personal
44 experience (Yamashita et al., 2012). Meanwhile, light source in fishing attraction by light, which mainly
45 includes filament lamp, halogen tungsten lamp, mercury and metal halide, all belongs to thermal light source
46 (Hua and Xing, 2013). The light from these lamps is omnidirectional and, therefore, most of it does not reach the
47 target areas, such as the deck and the surrounding water (Lai et al., 2015). Although these sources have improved
48 light intensity, their main handicap is that these lamps consumed a great amount of electric energy and fuel
49 (Kehayias et al., 2016).

50 Compared with these conventional lamps, LED (light emitting diode) have many advantages, such as high
51 efficiency, a long lifetime, fast response and together with climate resistance (Lai et al., 2015). Furthermore,
52 LEDs, which do not contain mercury (as opposed to CFL), are tolerant of low voltages, very small and portable,
53 and have high optical efficiency. LEDs are often submersible, and it can be compared favourably, technically
54 and economically with all other forms of lighting for small-scale applications (McHenry et al., 2014). Thus,
55 LEDs have been considered the most promising new lighting solution for a fishing fleet.

56 The objective of this research is to compare and to analyse the effectiveness of LED lamps application by using
57 catches and fuel consumption indicators. The results from this research can be considered to replace the
58 traditional CFL lamps with LED fishing lamps that was more efficient and environmental friendly to promote
59 sustainable fisheries at Bagan fishing in Banten Bay Indonesia.

60

61 **Material and Methods**

62 Lift net fishing in Banten Bay used varies CFL lamps with ranged of output power between 24 W to 90 W per
63 unit. In this research, we tried to introduce the new LED lamps and analysed the effectiveness of both lamps
64 based on catch weight and fuel consumption. Light sources in this experiment are white LED lamps (Fujilight
65 bulb 30 W, 2500 lumens) and white CFL lamps (Cahaya 4U model 90 W, 2400 lumens). These lamps were
66 chosen based on several reasons. The CFL lamps are an existing light source that was used by local fishermen
67 because low price, easy to be obtained, and bright enough to attract fish schooling. Meanwhile, LED lamps have
68 very long operating life, small, low energy consumption (Shen et al., 2012; Matsushita and Yamashita, 2012;
69 Hua and Xing, 2013) and they have similar lumens output with CFL lamps based on manufacture specification.

70 The CFL and LED lamps have different model and construction. They will affect to difference of light
71 distribution of both lamps. To analyse the pattern of light distribution, we investigated the illuminance of both
72 lamps in air and bottom of the sea water. Measurements of luminous intensity in air were performed in dark
73 room at Fisheries Department Laboratory Sultan Ageng Tirtayasa University using digital lux meter (Lutron
74 model LX-103 min scale 1 lx). The light intensity distributions were investigated by rotating sensor at every 10-
75 degree with radius 1 m from the light source to the sensor (Wisudo et al., 2002).

76 Fishing operation was conducted at 2 fixed lift net in Banten Bay with coordinate of LED and CFL lamps at
77 05°58'02"S; 106°09'40"E and 05°58'05"S; 106°09'58"E, respectively. The platform size of both bagan was 14 m
78 length, 14 m breadth and 12 m depth. Its box-shaped net was 12 m length and 12 m breadth, with 3 mm mesh
79 size of polyamide. Light illuminance of LED and CFL lamps at night in sea water was measured by underwater

80 lux meter (LUW 1000D) at sea surface to 10 m depth during fishing operation. The measurements were
81 conducted at the centre, middle and corner of platform with 1 m interval (Figure 1).

82 The first lift net used 6 units of CFL (each lamps is 90 W) and the second bagan used 6 unit LED (each lamps is
83 30 W) to attract fish schooling into catchable area. The fishing operations were conducted from 7:00 PM to
84 05:00 AM and the lamps were turned on between 2-4 hours every setting process. The catch data were recorded
85 soon after hauling by sorting the fish based on species, and then weight measured for each species. Fuel
86 consumption of gasoline generator was investigated by adding new fuel using measuring glass every morning
87 after finishing the fishing operation.

88 Light distribution of LED and CFL lamp in air presented and compared graphically as radar diagram. Luminous
89 intensity of both lamps in sea water shown as graphic of light intensity distribution pattern and describe
90 descriptively. Catch weight (kg) and fuel consumption (l) data were evaluated graphically and performed by *t*-
91 test analysis ($\alpha = 0.05$). The graphical comparisons of catch weight combined across with fishing trip using total
92 catch, main catch and proportion of main catch that expressed as a percentage of main catch.

93

94

95 Results

96 Distribution pattern of luminous intensity (lux) of the CFL and LED lamps in the air shows in Figure 2. The light
97 distributions of CFL lamp have main area around the left and right side. Meanwhile the LED lamp has majority
98 of illumination on the bottom of the bulb. The maximum intensity of CFL and LED lamps are 775 lx and 783 lx
99 respectively.

100 Light illuminances in sea water from CFL and LED lamps have different distribution as shows in Figure 3. The
101 LEDs have higher intensity in surface water until 5 m deep than CFLs, but the both light source have similar
102 characteristics at 5 to 10 m deep. Light distribution of LED light is more effective and it has homogenous pattern
103 on vertical and horizontal direction. Meanwhile the CFLs are slightly different on vertical, especially on the
104 centre of lift net that have lower intensity than left and right side. The illumination zone for CFL lamps is narrow
105 than LED lamps and it will affect to catchable area on fish capture process.

106 A total of 120 operations were conducted on 20 days fishing trip by 2 lift net during 22 May-16 June 2015.
107 There was no fishing trips around the full moon (1-5 June) and fixed lift net located in shallow water of Banten
108 Bay less than 15 m deep. The total catch from 2 lift net is 616.57 kg (mean 15.41 ± 0.15 SD). The highest catches
109 is 310.50 kg on lift net that using CFL lamps. The daily catch of CFLs ranged from 6 to 39 kg (mean 15.53 ± 8.94
110 SD) and LEDs have varied from 7 to 31 kg (mean 15.30 ± 6.10 SD). Figure 4 shows the daily catch from each lift
111 net during experiment. There are no significant different between the total catch of CFL and LED lamps.

112 Anchovy (*Stolephorus* sp.) is an economic commodity that becomes main target species of lift net fisheries.
113 Figure 5 shows the daily catch of anchovy during experiment. There are a significant different of catches
114 between LEDs and CFLs on trip 1, 3, 5, 6, 8, 9, 11, 13, 17 and 20, respectively. Lift net with CFL lamps get high
115 catches on trip 8, 10 and 19, meanwhile LEDs have more catches on other fishing trip. The maximum catches of
116 LEDs and CFLs were 15.4 kg (mean 9.82 ± 3.72 SD) and 14.0 kg (mean 8.09 ± 3.11 SD) respectively.

117 Catch composition during experiment shows the LEDs fixed lift net dominated by *Stolephorus* sp (61.77%),
118 *Sardinella fimbriata* (14.70%), *Leiognathus* sp (14.20%), *Terapon* sp (3.96) and others species (5.29%). The

119 CFLs catches also dominated by *Stolephorus* sp (59.99%), followed by *Sardinella fimbriata* (22.60%),
120 *Leiognathus* sp (8.18%), *Terapon* sp (5.61) and others species (3.61%). Meanwhile there was no significant
121 difference between daily total catch of each lamp (p-value 0.2218). Figure 6 shows the proportion (%) of
122 catches weight of LED and CFL during fishing operation. There are slightly different of catches between LED
123 and CFL almost on every fishing trip. The application of LED lamps can get 25% to 90% of anchovy (mean
124 67 ± 21 SD), while CFL lamps produce 33% to 83% (mean 58 ± 14 SD). The field experiment of the LED lamps
125 presented no technical problems, especially for the maintenance and replacing the CFL lamps. Specifically,
126 overall increase of main catches using LED lamps of 29%.

127 The lift net fishing used gasoline generator as a main source of electric power. The maximum output of the
128 generator reaches 2,000 W. Duration for lighting in one day trip approximately 10 hours (07:00 AM to 05:00
129 PM). Fuel consumption of CFL lamps is higher than LED lamps as shows in Figure 7. Fishing operation using
130 LED lamps consumed 3.30 to 5.30 l/night (mean 4.11 ± 0.61 SD), while CFL lamps consumed 5.20 to 7.00 l/night
131 (mean 6.33 ± 0.54 SD). Fuel consumption rate (l/h) under various lamps showed different tendencies. When all
132 the lamps were turn on, lift net with LED lamps consumed 0.33-5.33 l/h for lighting output 180 W and lift net
133 with CFL lamps consumed 0.52-0.70 l/h against 560 W output.

134 Figure 8 shows the reduction of fuel consumption (%) on lift net operation using LED lamps. Replacing CFL
135 with LED lamps will decrease of fuel consumption during fishing experiment. Reduction of fuel consumption
136 ranged from 18% to 45% (mean 35.15 ± 7.76 SD). The LED is an appropriate lamp technology for the lift net
137 fisheries especially to reduce fuel consumption and promote the environmental friendly of small scale fisheries
138 in Banten Bay.

139

140 Discussion

141 The number of fixed lift net in Banten Bay on 2015 reaches 62 units and most of them used CFL lamps to attract
142 target fishes to the catchable area. Fishermen changed their pressurized kerosene lanterns with CFL lamps since
143 2000 to increase the productivity of lift net fishing operation. The fishers select appropriate CFL lamps based on
144 practical and economic reasons. In this case, low price, easy to used, easy to be obtained, and bright enough are
145 the main consideration that were underlie by local fishermen to select varies of CFL lamps. Nevertheless,
146 application of high output of CFL lamp (up to 90 W per unit) cause increasing of gasoline fuel consumption
147 during fishing operation.

148 It is evident from Figure 2 that LED produced high intensity at the bottom of lamps (angle 0° - 40° and 320° - 360°).
149 Meanwhile the CFL transmitted high intensity at both side of lamps (angle 60° - 100° and 260° - 310°). There are
150 significant different of light distribution because each lamps have different shape and constructions. The CFL
151 lamp has more surface area at the side (u-tube construction), so these sections have maximum light distribution.
152 Light emitted from the bottom of CFL comes from the bottom side of u-tube that had limited surface area and
153 causes the decreasing of light intensity from the lamp (Puspito et al., 2015). Moreover, light from LED lamp has
154 straight direction especially to the bottom area. LED light sources are highly directional and highly efficient light
155 emitters that can focus the light intensity (Shen et al., 2012). It causes maximum intensity at the bottom of lamps
156 position. The spectrum, intensity and light distribution of lamps have specific characteristics depends on shape
157 and purpose of lamps manufacture (Anongponyoskun et al., 2011).



158 Fishermen used iron lamp shade (350 mm diameter) to focus the light during fishing operation. The
159 characteristic of light sources cause different light distribution pattern in sea water, even if it used same lamp
160 shade. LED light distribution had deeper penetration and widely expanded than CFL light. The maximum
161 intensity of LEDs and CFLs at the sea water surface was 2,244 lx and 758 lx respectively on the centre of lift net
162 platform. There were different pattern of iso-lux contour from each lamps at more than 2 m depth. LED light
163 presented U-shape and CFL light have W-shape that decreased with increasing of depth water. It is related to
164 lamps design, construction and light characteristics from each lamp. Light from LED source have sharp
165 distribution and arrives enough at 15 m depth and have no extreme change in spectrum from the surface to 15 m
166 depth sea water (Okamoto et al., 2008). In this research, lift net fishing operation used the general lighting of
167 LED and CFL lamps that was not designed specifically as fishing lamps. Moreover, the light intensity decrease
168 rapidly related to the emergence angle and its distribution varied at target plane. The lens of LED source with
169 novel design using double freeform surface is an effective method to improve uniformity of light illuminance
170 from 67.20% to 86.43% (Wu et al., 2015).

171 The light illuminance and distribution from both lamps around fixed lift net platform have similar effectiveness
172 to attract fish into catchable area. Mean catch per unit effort in squid jigging fishery using only 216 LED lamps
173 lower than using 78 Metal Halide Lamps, because LED lamps irradiated only a limited area near of vessel
174 (Shikata et al., 2012). Catch weight of boat lift net using flood LED lamps also lower than mercury lamps
175 (Sulaiman et al., 2015). It was indicated the general lighting of LED lamp cannot used directly as effective
176 fishing lamp on capture fisheries. Fish behaviour and response related to light emitted of LED were investigated
177 to improve design and to obtain an appropriate specification of the new generation of fishing lamps in fishing
178 activities (Mills et al., 2014). The new design of white LED lamps used multi-segmented freeform lens (MSFL)
179 can perform better as fishing lamps, 3 times more efficient, than the traditional High Intensity Discharge (HID)
180 lamp (Lai et al., 2015).

181 The anchovy as main target species of fixed lift net in Banten Bay has high economic value (Indonesia
182 Rupiah/IDR 75,000 – 90,000 per kg/United State Dollar/USD 5.77-6.92 per kg). LED lamps application in this
183 experiment had significant effect to catch weight of anchovy (p-value 0.0087). It is evident from Figure 5 and 6
184 that catches weight and proportion of main catch using LED lamps is higher than CFL lamps. Previous
185 researches show varied result of LED performance in fishing operation. Combination of LED panel with 24
186 metal halide lamps presented highest catch of Japanese common squid (Yamashita et al. 2012). Light from white
187 LED lamp could penetrate to deeper water and caught more white anchovy (*Stolephorus indicus*) than mercury
188 lamps (Sulaiman et al., 2015a). Blue LED was recommended to gathering the squid and white LED was very
189 useful to squid fishing (Jeong et al., 2013). Fishing experiment using LED and metal halide lamp in Korean
190 squid jigging fisheries presented that catches of squids per the fishing vessel with 1 W LED fishing lamp were
191 higher up to 135.5% than the fishing vessel with metal halide (An, 2014). Main catch (*Stolephorus* sp.) per unit
192 energy of boat lift net in Sulawesi using LED and mercury lamp is 11.61 kg/W and 3.77 kg/W respectively
193 (Sulaiman et al., 2015b).

194 White LED in this research have dominant wavelength at 450 nm and 590 nm. It is similar properties with Bae et
195 al. (2011) that used the dominant wavelength of white LED at 450 nm and 550 nm to attract *Engraulis*
196 *japonicus*. Characteristic of fishing lamps will have affected to catch weight and species composition. It is



197 related to behaviour and response of fish to light attractant. Each species has different maximum absorbance of
198 light spectrum depend on structure and morphology of retinae. *Stolephorus indicus* have poly-cone type with
199 cone density $684 \times 10^4 \mu\text{m}^2$. It is indicate that retinae of this species very adapted to light stimulant (Heb et al.,
200 2006). *Engraulis japonicus* and *Engraulis encrasicolus* have triple cone with maximum absorbance wavelength
201 approximately at 502 nm, while the short central components were more shortwave sensitive ($\alpha_{\text{max}} = 475 \text{ nm}$).
202 The α_{max} of all long and short cones in the ventro-temporal zone was 492 nm, compared to 502 nm in other
203 retinal regions (Kondrashev et al., 2012). The dominant catch of *Stolephorus* sp. during experiment indicated the
204 transmitted wavelengths from LED lamps were appropriate enough to the maximum absorbance of anchovy. It
205 schooling influenced, gathering and stay into catchable area for the long times as a response of light adaptation
206 behaviour.

207 LED lamps had lower fuel consumption than CFL during fishing operation. It is evident from Figure 7 and 8 that
208 LED is efficient light source with mean saving energy up to 35%. Application LED lamps in fixed lift net in
209 Banten Bay had significant effect to reduce fuel consumption (p-value 5.01×10^{-14}). LED fishing lamps in hair-
210 tail angling at Korean fisheries had higher fishing performance, save 33% of fuel consumption, decreased the
211 operation expenses and green house emission (An et al., 2012). Fishing experiment at purse seine and squid
212 jigging fisheries showed LED lamps have high productivity and lower fuel consumption than metal halide
213 lamps. LED lamps save 50% of fuel than metal halide (Hua and Xing 2013), more efficient up to 80% than high
214 intensity discharge (Shen et al., 2012) and save 24% of fuel in Japanese squid jigging fisheries (Matshushita et
215 al., 2012). Application LED lamps in Korean squid jigging industries also decreased 65,163 kl of fuel
216 consumption in a year (Park et al., 2015). In small scale fisheries, replacing CFL lamps with LED lamps save
217 37.5% of fuel consumption in fixed lift net at Lesung Cape Banten Province (Arif et al., 2015).

218 In conclusions, we found the light distribution of commercial LED lamps could penetrate wider and deeper to
219 the catchable area than CFL lamps and were good enough to attract the target species of anchovy. Application of
220 LED lamps had significant effect to the catch weight of anchovy and save fuel consumption. The LED lamps are
221 the potential suitable light source for replacing CFL lamps and developing sustainable lift net fisheries in Banten
222 Bay.

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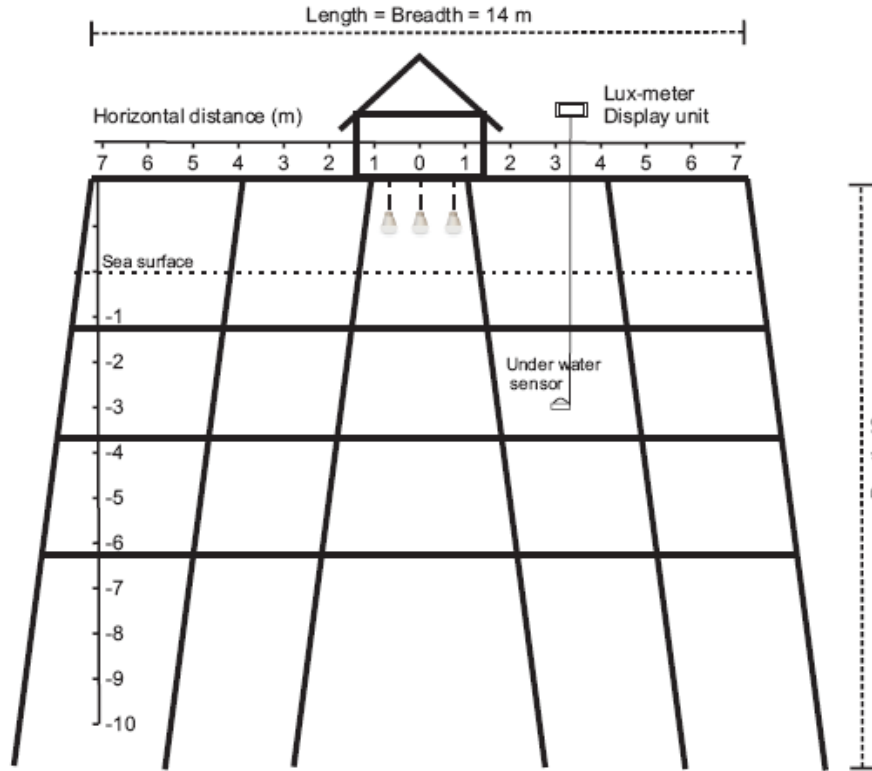
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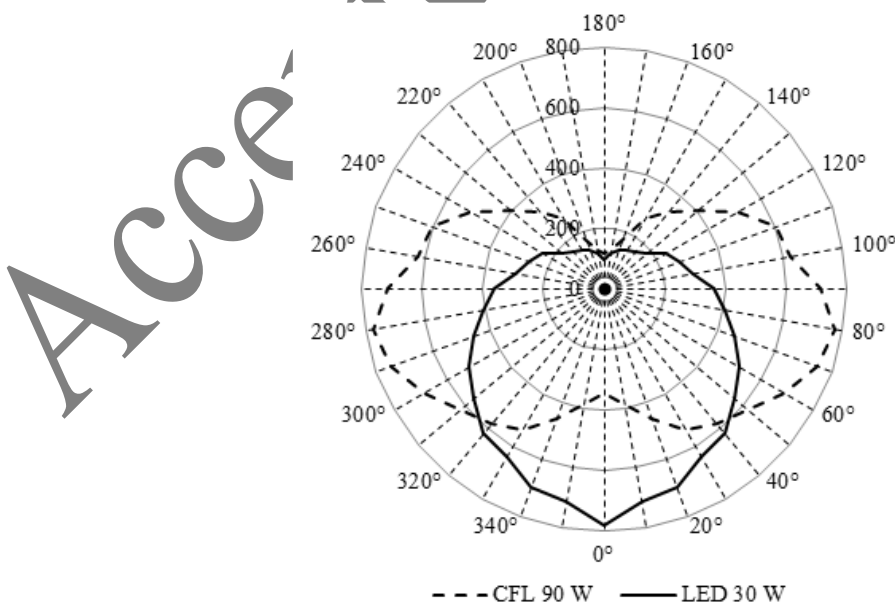


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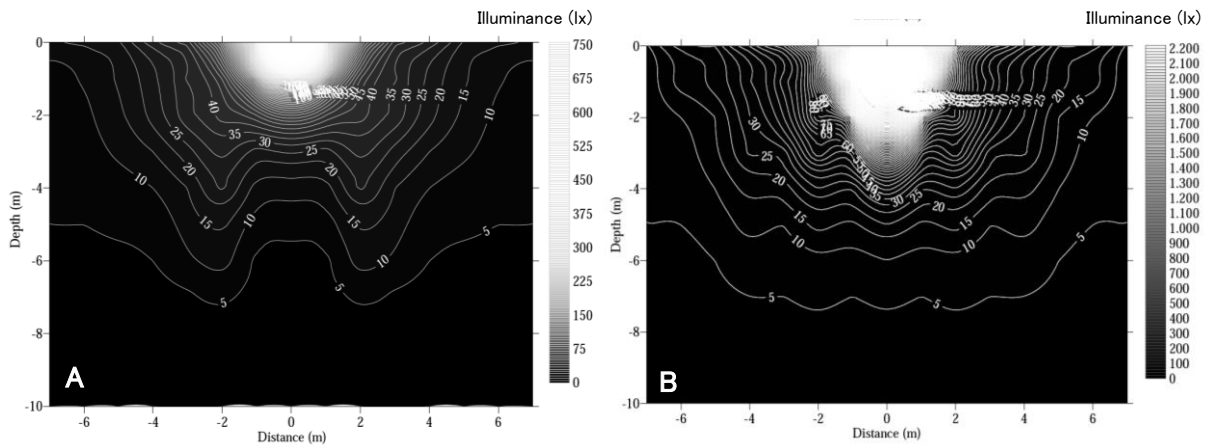
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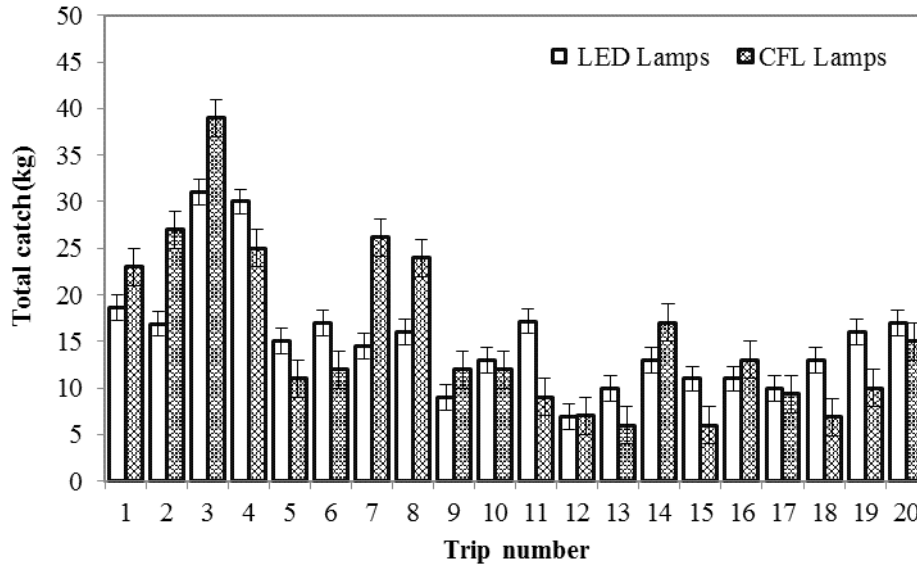
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310 **Figure 1.** The arrangement of light intensity measurement in sea water.
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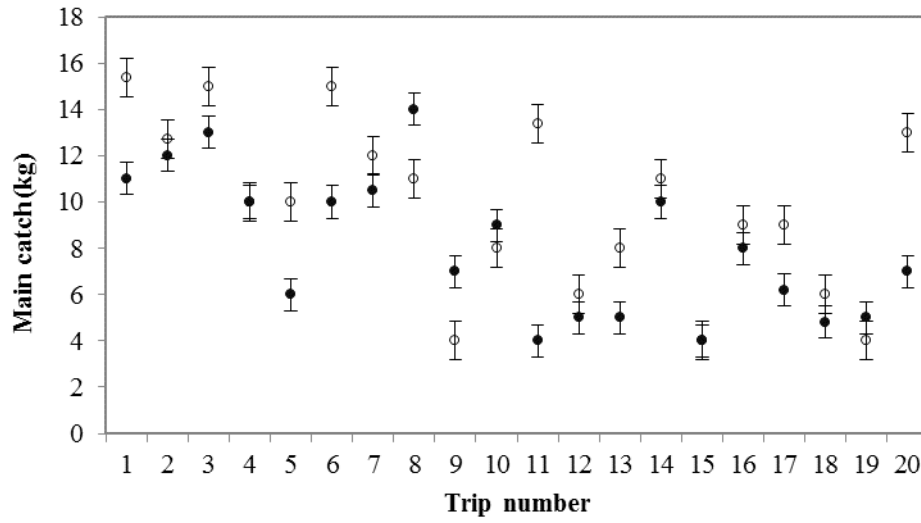
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313 **Figure 2.** Distribution of light intensity of CFL and LED lamps in the air.



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315 **Figure 3.** Sea water light distribution of CFL (A) and LED (B) lamps.
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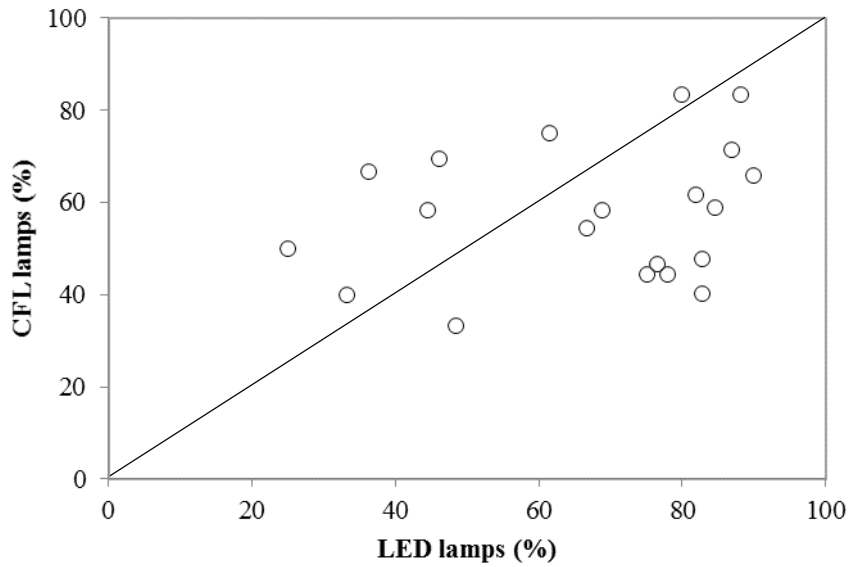


317
318 **Figure 4.** Daily catch of CFLs and LEDs lamps (Vertical lines denote standard errors).
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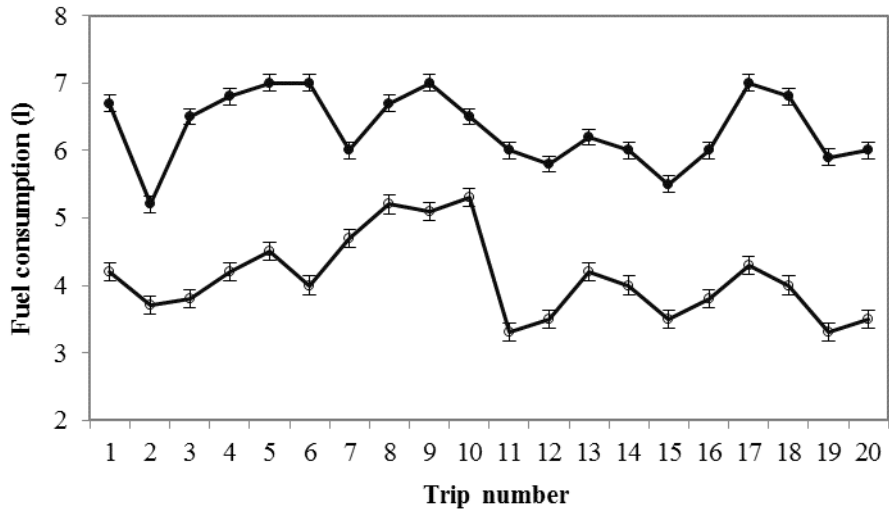
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Figure 5. Daily main catches of lift net with LED (circle) and CFL (point) (Vertical lines denote standard errors).



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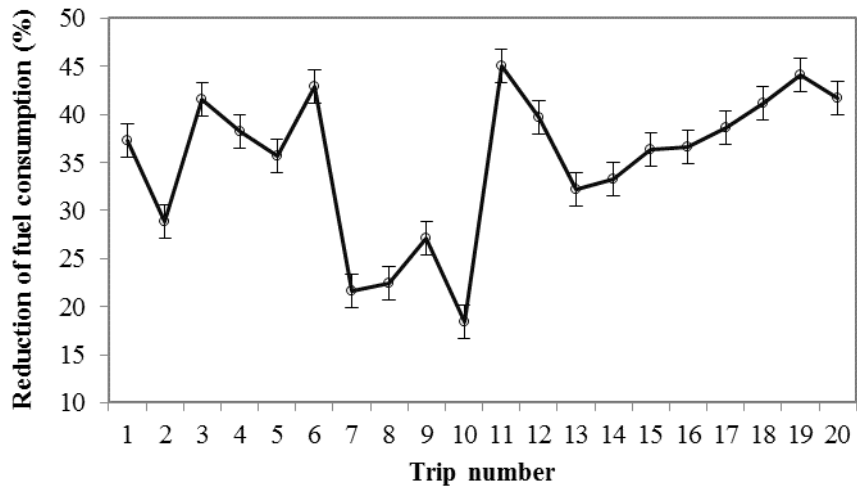
Figure 6. Proportion (%) of lift net main catches using LED lamps plotted against CFL lamps.



327

328 **Figure 7.** Fuel consumption of lift net using LED (circle) and CFL (point) (Vertical lines denote standard
329 errors).

330



331

332 **Figure 8.** Reduction of fuel consumption of fixed lift net using LED lamps (Vertical lines denote standard
333 errors).

334