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RESEARCH PAPER

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Efficiency Comparison of LED and MH Lamps in Purse Seine Fisheries

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Abstract

Metal halide (MH) lamp is applied in light fishing purse seine (PS). This lamp have weaknesses like wasteful energy, it is necessary to replace with energy saving lamp. Light emitting diode (LED) is potential to replace the MH. The experimental method in order to obtain data on different light intensity, fuel consumption, and number of catch in PS fishing using MH and LED lamps as fish attractor. Light intensity observations were done on each of 6 MH and LED lamps in the distance of 0-17 m. The LED lamp had focus more onto the front that enabled to reach farther distance, MH lamp had dispersed illumination distance. The LED lamp is more efficient in directing the lamp into the water. The number addition of MH lamps on different side of vessel does not increase the total amount of light intensity significantly. The ratio of the number captures of MH and LED lamps is 3.57:1 is much lower than the electric power ratio of both lamps (40:1). So that if the electric power LED lamps increased 6.2 times from 600 W to 3,875 W then the total number of fish from the LED lamps will approach the MH lamps.

Introduction

Purse seine (PS) is one of the productive and developed fishing gear in the world (Sudirman & Musbir, 2009). This fishing gear is also operated in the night using lamp to gather positive phototactic fish (Okamoto, 2010).

The type of lamp developing in lamp fishing of purse seiners in Lamongan is the use of metal halide (MH) lamp. It is liked because of its very bright lamp so that its light can penetrate far down below the waters surface and can be seen by the fish from long distance. This confidence makes the fishermen continue to add number of the MH lamps on board to have brighter lamp. The addition of number of MH lamps needs bigger electric power of generator set (genset) and as a consequence more fuel consumption. The fishermen will not think of higher due to the fuel consumption of the genset.

High light intensity of the MH lamp is caused by its large electricity power, 1,500 watts (W) per bulb. Total MH electricity power utilized on the purse seiners ranges from 15,000 to 30,000 W to make the light be stronger (Matsushita, Azuno & Yamashita, 2012). Bright condition in fishing ground, as mentioned by Arimoto (2013) occurs as if it is a 'lamp war'.

Nevertheless, behind the brightness of MH lamp, it possesses some weaknesses, such as wasteful electric, wasteful fuel and environmentally unfriendly (Takayama & Arimoto, 2010; Seo, An & Do, 2012; Shen, Kuo & Fang, 2013). According to Hua and Xing (2013) that some of this electric power is converted to heat energy that can influence the ship crew's health and daze the eyes of juvenile and young fishes. Hua and Xing (2013) also stated that this type of lamp is physically easily broken and short-lived due to sensitive blazing wire, easily short-circuited, and holding heavy metals, infra red (IR) light and ultra violet (UV) light. Therefore, the use of LED lamp needs to be studied due to being safer energy. Nowadays, its utilization as fish attractor has not many been applied in Indonesia. Meanwhile in developed countries, this type of lamp has high application to replace the MH lamp because of saver fuel consumption (Yamashita, Matshushita & Azuno, 2012; Tak, 2008; An, Bae, & Park, 2013).

LED lamp is a type of semi-conductor diode lamp with direct current direction and can be illuminated in a variety of colors that emit incoherent monochromatic lamp when given a forward voltage (Okamoto, 2010)**.** It is also save of energy and long-life, 60,000-100,000 hours (Hua & Xing, 2013), and has high efficacy, 125 lumen watt^{-1} (Philips Indonesia, 2013). This lamp has low electricity power and 50% saver than the MH lamp. The lamp source is cooler (type of environmentally friendly lamp) and does not contain infra-red and ultra violet components, and mercury element. It does not also result in radioactive contamination (no hazardous substance), the waste could be recycled, and no pollution occurs so that the fisheries ecological damage could be prevented (Hua & Xing, 2013). Fisheries of LED lamp have several superiorities compared with the conventional lamp metal halide, 30 times more energy efficient, higher durability and small environmental impacts (Okamoto, 2010; Shen, Li & Huang, 2014).

Increased fuel price from year to year has made fish capture business be not economic (Beare & Machiels, 2012; Suuronen, Chopin, Glass, Lokkeborg, Matsushita, Queirolo & Rihan, 2012). Improvement of fuel cost efficiency could be done through replacement of the wasteful energy MH lamp with more efficient LED lamp (Kowadenkisangyo Co.Ltd., -; Aman, Jasmon, Mokhlis & Bakar, 2013; Susanto, Irnawati, Mustahal & Syabana, 2017). The LED is superior due to the use of low electricity power at high light intensity so that the fuel consumption will be low. This study was intended to compare and analyze the efficiency of LED lamp and MH lamp based upon lamp intensity, lamp illumination pattern, fuel consumption, and number of catches. This finding could be used as consideration to replace the use of MH lamps with the LED lamps in purse seine fisheries in Indonesia.

Materials and Methods

Equipment and Method

Phase I. Lamp Intensity Observation

This activity was at night on September 17th, 2016.

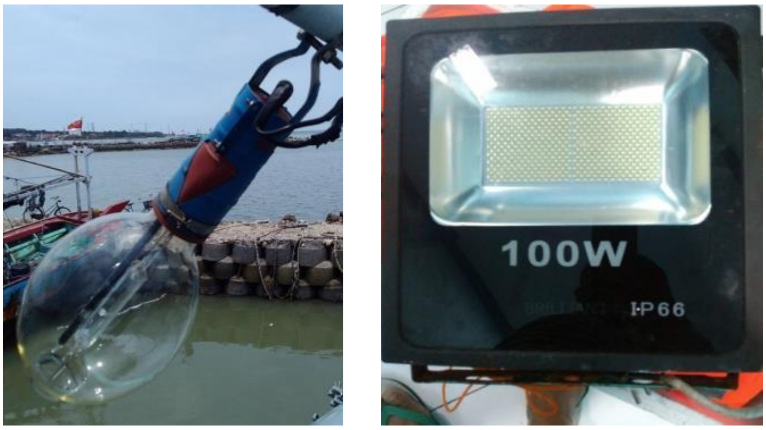
The equipment used were MH lamps, LED lamps, iron mast, diesel generator, and lux meter.

The light intensity was measured using 1010A-typed auto digital lux meter, Victor merk with a capacity up to 50,000 lux. Six Sammyung-MH lamps of spherical shape made in South Korea were used, each of which was 1,500 W (Figure 1a). LED lamp had 100 W, rectangular shape of 27 × 30 cm casing, merk Brilliant IP66 made of China (Figure 1b) wherein containing 100 LED tiny particles.

Light intensity measurement was done on shore at the dark location. It could result from difficulty of doing on board at unstable surface condition. The lamp was positioned at the center floor of gymnasium on the iron mast 5 m from the floor (Figure 2). This lamp position was as if the lamp on the ship board when measured from the sea level. The indoor condition was made darkness, and the outside lamp was turned off so that no light entered from outside. The measurement was done at the one-quarter of the floor gymnasium (quadrant I) at the angle of 0^{o}, 22.5^{o}, 45^{o}, 66.5^{o} and 90^{o}. A 10,000 W-diesel generator was employed to swift on the generator. The areal limitation of 20 × 40 m-sized room made the farthest distance measurement position of 19 m at the angle of 0^{o} and 9 m at 90^{o}, respectively.

Phase II. Catch Data of Purse Seine with MH and LED Lamp.

Data were collected by involving in fishing operations. Research equipment used was 16 m LOA purse seiner fishing vessel. The boat used one unit of purse seine with 400 m long, 50 m depth, and 2.5 cm of mesh size, in fishing operation 1 using MH lamps and fishing operation 2 using LED lamps. The net was made from green-colored polyamide multifilament. The MH lamps were used as control treatment, since this type of lamp has been used by the fishermen to fishing at night**.** As many as 16 MH lamps were placed in parallel position on the boat, 8 lamps on the right and the left sides, respectively (Figure 3a). To operate the MH lamp a 40,000 W-diesel Mitsubishi PS 120 genset onboard was prepared, while 6 LED lamps were placed on the floating



a b

Figure 1. MH lamp (a) and LED lamp (b).

construction called bangkrak, 2 on the left side, 2 on the right side, one each on the fore and the rear sides (Figure 3b). To turn on the LED lamps, a genset of 4,000 W was also put on the float**.** The bangkrak was laid down from and lifted to the boat using a crane. It was 2 × 1 × 1 m^3 supported with 2 styrofoam floats. The study was carried out in Paloh Village, Paciran District, Lamongan Regency, East Java, Indonesia, which local fishermen operated their purse seine using light attractor. They usually fishing at the fishing grounds equipped with fish aggregating devices (FAD) in the north of Lamongan Regency waters, at the geographic position of 6°33'11.6" S and 112°43'28.7" E (Figure 4), and research period was from September to November, 2016.

Fuel Consumption Measurement

Fuel consumption was measured during the fishing operation. It is theoretically calculated (Ariyanto, 2016) using the formula of 0.21 × *P* × *t*, where 0.21 is a contant, *P* is genset power (watt) and *t* is time length of generator operation (hour). This theory requires that the engine condition is new but in used generator, it is more valid to do by directly observing the fuel consumption on the fuel tank. Thus, this study applied manual fuel consumption measurement. The measurement was carried out through observation on the residual fuel volume in the generator's fuel tank on the vessel deck and on the bangkrak lamp float after the illumination had been terminated (Vt). These data were taken after the fishing vessel had arrived at the port from fishing operations. Generator's fuel consumption (Vk) is the amount of the fuel volume used during the lamp activation to attract the fish school. The amount of fuel consumption is initial volume of the fuel tank (Vo) diminished with residual fuel volume in the tank (Vt).

$$Vk = Vo - Vt \quad (1)$$

Catch Data Collection

Fishing operations were conducted in 15 trips using each of MH lamp and LED lamp. When arriving at the fishing ground 1, the vessel put down the bangkrak with LED lamps that have been already turned on. Then the vessel continued to fishing ground 2 and the MH lamp on board was switched on. The fishing target species were the positive phototaxis fish. After waiting for 5 hours, the vessel started setting purse seine to catch the fish gathering around the MH lamp**.** After hauling, the fishing vessel went back to the bangkrak to catch the

Figure 2. Measurement position of light intensity for MH and LED lamps.

Figure 3. Fishing vessel with MH lamps (a) and bangkrak float with LED lamps (b).

fish coming to the LED lamp (setting-hauling 2). The fish catches in setting-hauling 1 and 2 were separated on board in each trip to enable to record the fish species and number of catches in each lamp used**.** Fish sorting process was conducted on the way back to shore, and fishes of different species were put in separate plastic basket. The fish were also weighed and separated depend on the lamp type used.

Data Analysis

The light intensity data were processed in the form of line diagram demonstrating different intensity of MH lamp at the angle of 0^o, 22.5^o, and 45^o of various distances (0-17 m) and different numbers (1-6 lamps). The light intensity difference between LED lamps and MH lamps are demonstrated in the form of polar diagram. In this study, the electric power of the LED lamps on the bangkrak cannot be set to be homogenous with that of MH lamps on the purse seiner. It could result from no LED lamps used on the fishermen's fishing vessel yet, so that the LED lamp could not be used on the purse seiner.

Results

Light Intensity

Limited space of the gymnasium building made the farthest measurable distance from the lamp was 19 m at 0^o angle and the nearest distance was 9 m at 90^o. From 5 measurement angles at quadrant I, the largest distance 17 m was found at the angle of 0^o, 22.5^o and 45^o (Table 1), while at the angle of 66.5^o and 90^o, the measurable distance was less than 17 m. The light intensity of 1 MH lamp was lower, 67.5-71.3 lux, than 2-6 MH lamps. The highest light intensity was recorded at the distance of 1-3 m and the lowest at 17 m distant. The output of light intensity (lux) data processing of MH lamp with different numbers, angles, and measurement distance are presented in Figure 5 as follows:

1. The highest light intensity at all angles, 2 m distant from 0 m position under the lamp, was found in the use of 4 MH lamps, followed with 3, 5, 6 MH lamps. It means that the MH light intensity will rise with addition of MH lamp on the same vessel side.
2. The lowest light intensity of 6 MH lamps occurred in the farthest distance, 17 m, with relatively same value for 2-6 MH lamps at the range of 50-100 lux. At the farthest distance, the light intensity of all MH lamps are almost same at low.
3. The light intensity of MH lamp at the nearest position, 0 m (under the lamp source), was lower than that at the distance of 1-3 m. Afterwards, the light intensity will get lower with farther distance from the light source.
4. The measurement data of light intensity of quadrant I was symmetrically plotted to those of quadrant II, III, and IV, forming 360^o-circle in line with sphere shaped MH lamp illumination patterns. Meanwhile, the LED lamp formed a quarter circle of illumination, 90^o, to forward direction. The light intensity and the distribution pattern of LED and MH lamps are presented as polar diagram.

Fuel Consumption

During the study, the generator's fuel consumption

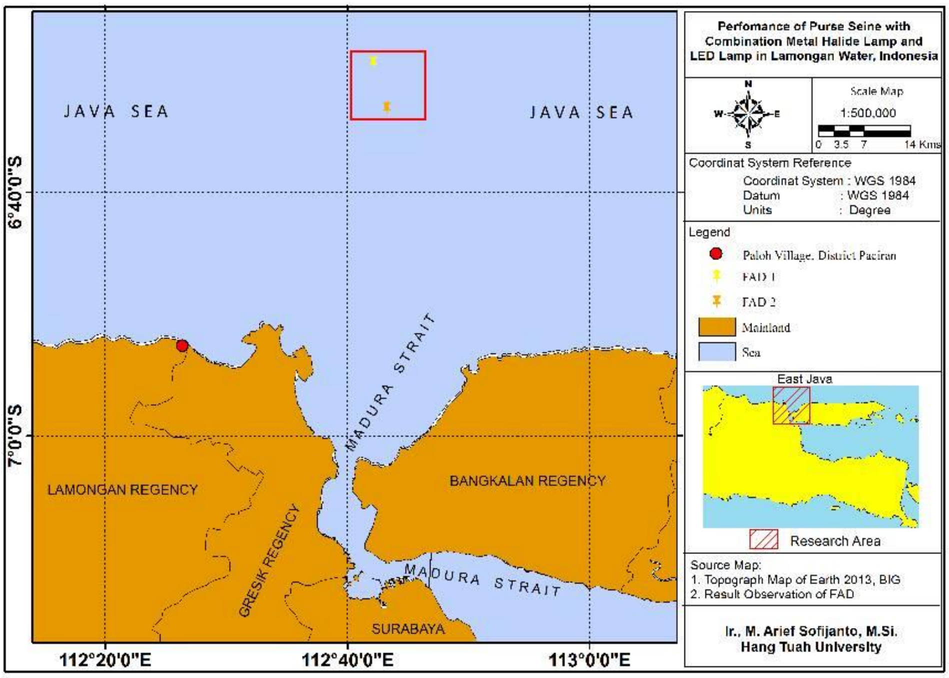


Figure 4. Map of research location and fishing ground.

Table 1. Light intensity of MH lamp (lux) at different angles and distances

Angle 0°

MH	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	28.7	26.4	58.5	70.1	71.1	67.2		51.1	42.9	37.2	32.3	27.8	24.6	20.7		17	14.7	14
2	304	335	372	361	299	247		172.5	144.2	126	109.9	100.1	88.2	78.5		63.1	57.9	52.7
3	503	491	539	470	413	447		252	225	193	163	141.7	135	118.1		96.7	84.9	77.8
4	523	541	571	476	425	324		266	215	187.1	174.6	158.8	141.4	127.6		106.4	94.8	85.1
5	530	552	535	459	383	301		267	238	213	199	163.4	146.7	135.2		112.5	98.5	87.3
6	431	347	345	292	234	186.4		169.3	146.2	136.7	115.6	107.5	97.4	88.5			67.1	60

Angle 22.5°

1	52.4	59.9	64.8	67.5	64.1	57	52.9	47	40.4	36.6	32.6	27.8	23.7	21.1	18.8	15.4	15.2	14
2	259	330	328	339	319	294	249	215	172.9	156.2	138.4	118	104.5	91.3	77.3	73.3	64.9	60
3	433	447	474	403	352	311	269	235	235	212	188.8	158	139	121.6	111.3	94.1	89	80.4
4	485	534	504	465	433	392	293	262	220	206	183.8	167.8	155.6	138.8	128.7	117.2	106	94.5
5	493	507	483	459	426	379	301	253	237	202	173.8	163.3	147.8	136.8	124.6	116.1	105.7	93.7
6	327	347	322	313	281	249	194	162.1	141.5	132.7	116.3	110.4	105.4	94.4	87.7	77.9	69.7	64.7

Angle 45°

1	67	69.2		58.6	53.4	56.5	39.7	33.8	30.9	28.7	25.2		19.3	17.2	15.5	13.7	12.9
2	184.9	408	392	338	290	242	204	173.9	149.2	128.6	110.4	93.5	82.9	77.2	68.9	62.9	55.9
3	376	503	490	426	372	310	267	225	183.1	165.5	145.1	131.5	114	105.8	93.4	86.7	77.1
4	399	527	498	449	392	336	290	249	217	188.1	168.4	149.5	135.2	119.9	107.9	98.1	87.9
5	427	501	479	438	369	310	265	237	207	180.8	170.9	149.9	135.7	121.9	110.6	102.8	92
6	280	335	310	267	224	188	168.9	147.6	130.5	119.2	105.8	93.2	82.2	75.6	65.3	62.2	56.5

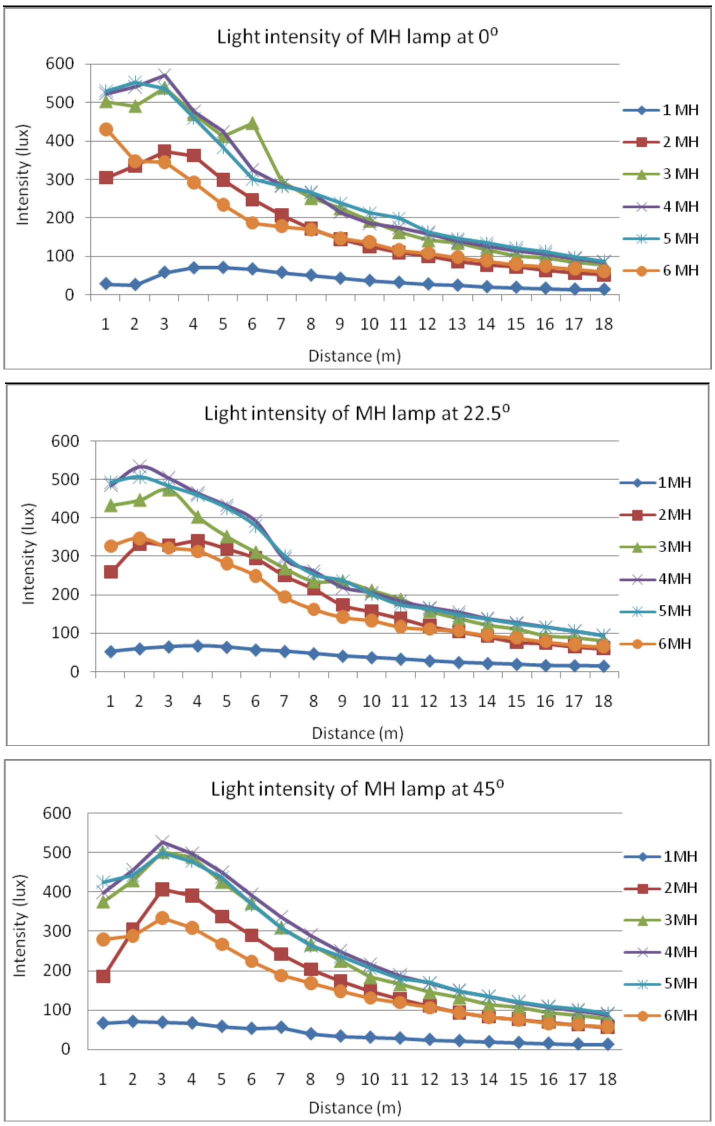


Figure 5. Light intensity comparison of MH lamps at 0°, 22.5° and 45°.

per trip to turn on all MH lamps were 35 liters for 5 hours (06:00 - 11:00 PM) or 7 liters per hour, while that to switch on all LED lamps on the float was averagely 10 liters for 9 hours (06:00 PM - 03:00 AM) or 1.11 liters per hour. Meanwhile the cost of genset fuel per trip were IDR 197,750 for MH lamps and IDR 70,500 for LED lamps (Table 2).

Fish Catch Amount

During the study, the use of MH and LED lamps in fishing operations obtained different number of catches. However, both of the lamp types caught the same number of fish species, 15 fish species and one species of squids. It reflects that purse seiners could caught many 8 species of fish as typical characteristics of multi-species fish in the tropical waters (Gücü, 2012). The most dominant fish catches were scad mackerel (*Decapterus ruselli*), barred Spanish mackerel (*Scomberomorus gutatus*), eastern little tuna (*Euthynnus affinis*), and fringescale sardine (*Sardinella fimbriata*). Other fish species caught were black tipped penyfish (*Leiognathus splendens*), barracuda (*Sphyraena genie*), ribbon fishes (*Trichiurus lepturus*), purple spotted bigeye (*Priacantus tayenus*), silver pomfret (*Pampus argentus*), yellow strip trevally (*Selaroides leptolepis*), short bodied mackerel (*Rastrilliger brachysoma*), striped mackerel (*Rastrelliger kanagurta*), hail tail scad (*Megalaspis cordyla*), round hering (*Dussumieria acuta*), and frigate mackerel (*Auxis thazard*). These species were the same as the fish species attracted to mercury lamp and LED lamp in floating lift net in South Sulawesi (Sulaiman, Baskoro, Taurusman, Wisudo, & Yusfiandayani, 2015). Puspito, Ahmad. and Sururi (2017) said that pelagic fish come around the light source as plankton feeder.

Discussion

Light Intensity

The highest light intensity of the MH lamp, 504-571 lux, was recorded in the use of 4 MH lamp at the measurement distance of 1-2 m, followed by 5, 3, 6, and 2 lamp bulbs, respectively. This could be taken as reference that the largest light intensity of MH lamp on board occurred at the distance about 2 m.

At 0 m-distance (or vertically under the lamp), the light intensity was lower, 399-523 lux. The farthest measurement reachable in this study was 17 m using 2-6 MH lamps with nearly similar light intensity of about 52.7-94.5 lux. Its light intensity declined with distance, but it is relatively the same at the farthest distance despite addition of number of lamps. It occurred since when 4, 5 and 6 MH lamps was switched on, the light intensity measurement was done on one side at the position 1-3 MH lamps were set. This could be the reason why the addition of more and more MH lamps did not raise the light intensity. The highest light intensity at the distance of 2 m of the 5 angles was then symmetrized with the other 3 quadrants so that it formed a full spherical pattern in the form of polar diagram (360^o). The distribution pattern of MH lamp illumination was consistent with its spherical-shaped light bulb that supported polar illumination pattern (Figure 6a). The circular light intensity of 1 MH lamp (1,500 W) was stronger than that of 1 LED lamp (100 W). However, the light distribution pattern of the LED lamp was focused forward so that at the straight direction measurement of 0^o, the intensity of LED lamp was slamply bigger than that of 1 MH lamp. Whereas the distribution pattern of 3 LED lamps (300 W) with straight measurement direction of 0^o had much bigger intensity than that of 1 MH lamp so that its illumination distance could be farther than the use of MH lamp (Figure 6b). This is in agree with Sulaiman *et al*. (2015) that penetrability of the LED lamp is stronger into the water. According to Anonymous (2006), LED lamp illumination could focus at small angle so that it could penetrate the waters deeper. MH lamp formed a 360^o angle that made only few light be diffused into the water and the most portions were spread to the atmosphere (Puspito & Suherman, 2012). According to An and Jeong (2011) that under the brighter condition than 0.05 lux, white LED light was found to have the highest gathering rate of 41.5%.

Fuel Consumption

The amount of genset fuel consumption is dependent upon power capacity (watt,W) and time length of the genset operation (hour). The fuel consumption of LED lamp genset was lower than that of MH lamp, only 10 liters, despite longer operation time, 9 hours. The genset power on the floating construction was small since total LED lamp power set was small. In contrast, the MH lamp operation that had large total

Table 2. MH and LED lamps operation data per trip

Lamp type	Power (W)	Period (h)	FC (l)	FC per hour (l.h^{-1})	Cost of fuel (IDR)
MH	24,000	5	35	7.00	197,750
LED	600	9	10	1.11	70,500

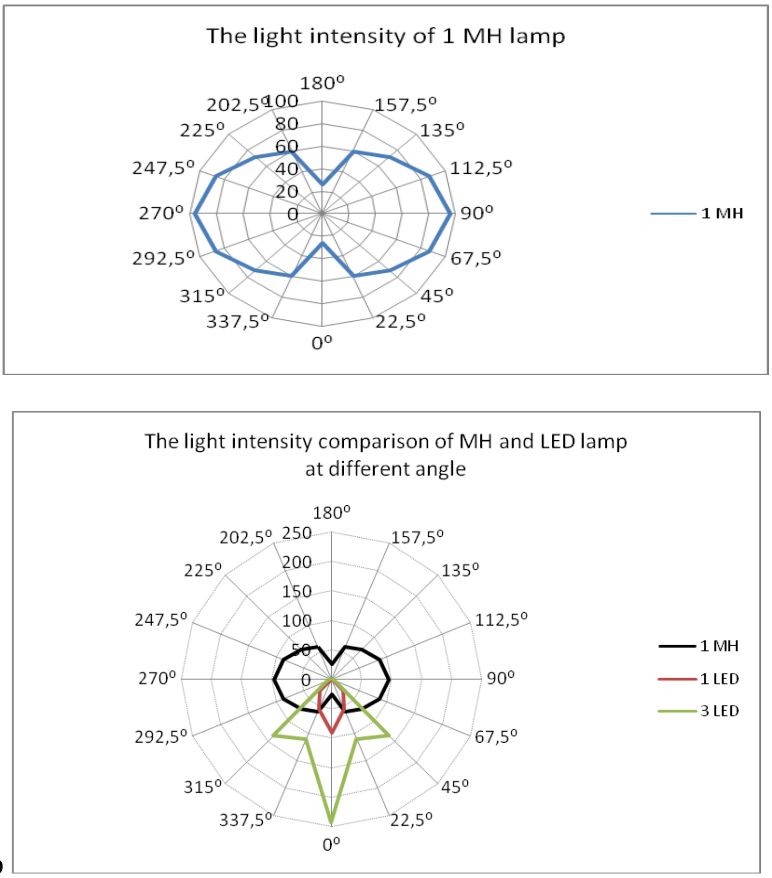
Note: l=litre; h=hour; W=watt;
FC: fuel consumption of generator set (l)
IDR: Indonesian rupiah

power required higher fuel consumption. This is in agreement with An (2013) that in ribonfish (*Trichiurus* sp.) season in Korea, fuel necessity increases since high number of MH lamps are operated to attract fish using big power.

The use of total power of MH lamp as many as 24,000 W has passed the regulation of Indonesian government with the regulation of MMAF numbered 71/Permen-KP/2016 for the purse seine less than 400 m long operating in the fishing track III (more than 12 miles), 8,000 W at the maximum (MMAF, 2016). The energy efficiency effort could be carried out using save energy lamp that enabled to employ a small power genset of lower fuel consumption. The fuel consumption per hour of genset was 7.00 l h^{-1} for MH lamp (IDR 197,750 per trip) and 1.11 l h^{-1} for LED lamp (IDR 70,500 per trip) indicating that the LED lamp was can use the smaller power genset which lower fuel consumption than MH lamp. It mean that LED lamp can be a new light source for replacing MH lamp (Wang, Qian, Kong, Ye & Lu, 2015).

Fish Catch Amount

During the study, the use of MH lamps obtained total catches of 23,247 kg (78.12%) of fish, while that of LED lamps gained 6,517 kg (21.88%) of fish (Table 3) or catch ratio of 3.6 : 1. This ratio is much smaller than the ratio of the total power of both lamp types 24,000 W : 600 W or 40 : 1 (Table 4). Nevertheless, if the catches were converted to per hour, the LED lamp had lower conversion, 48.2 kg h^{-1}, than that of the MH lamps, 310 kg h^{-1}. It reflects that the use of LED lamps if raised from 600 watts to 3,875 watts (6.2 times) then LED lamps capture will approach fish catch amount of MH lamps. This finding could become recommendation for the fishermen to replace the MH lamps with the LED in the same manner as practiced in the developed countries. The application of MH lamps in purse seine fishing operation had different number of catches from that of LED lamps indicated that the catch of MH lamp-purse seine was higher than that of LED lamp, with mean catch of 1,550 kg and 434 kg per trip, respectively. Yamashita *et al*. (2012) found that number of squid catches increased with number of MH lamps. In spite of that, according to Takayama and Arimoto (2010), the catch could rise, but the fuel consumption would also be higher with addition of number of MH lamps. The use of MH lamp is the development of previous fish attracting, such as petromax kerosene lamp, compact fluorescent lamp (CFL), halogen, and mercury lamp. Fish catch of MH lamp was higher than other previous lamps used. It, according to Anongponyoskun, Awaiwanont, Ananpongsuk & Arnupapboon (2011), could result from that the light intensity of the MH lamp was higher up to 10 m under the surface than that of incandescent lamp



a

b

Figure 6. Light intensity comparison of MH and LED lamps.

Table 3. Efficiency comparison between MH lamps and LED lamps per trip

Treatment of lamps	Fishing Catch (kg)	Period (h)	Weight convertion (kg h^{-1})	Power Equaliser (W)
MH (24 KW)	1,550	5	310.0	(24 KW)
LED (.6 KW)	434	9	48.2	3.9 KW
Ratio 40:1	3.57:1			6.2:1

Note: KW=kilowatt W=watt; h=hour; kg=kilogram

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and CF lamp. As conclusion, the distribution pattern of the LED lamp focused more on the fore direction, and the MH light dispersed. Under the same electric power, the LED lamp had higher light intensity than that of the MH lamp. Addition of number of MH lamps at the other position of the fishing vessel did not increase the light intensity. The highest was recorded at 2 m distance from the fishing vessel, not under the lamp (0 m). At the farthest distance, the light intensity of all MH lamps was almost be one. Number of catches were more in the use of MH lamps than LED lamps because of using larger total electricity power (watts).

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