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Original research article

The effectiveness of light emitting diode (LED) lamps in the offshore purse seine fishery in Vietnam

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ABSTRACT

Fishing with artificial light has become one of the most advanced, efficient, and common methods for the night-time purse seining in Vietnam. This study evaluated the radiation spectrum, CIE chromaticity coordinates, correlated color temperature (CCT), catch rate, fuel consumption, and CO_2 emissions when using Light emitting diode (LED) lamps (0.196 kW) in comparison with the use of metal halide (MH) lights (1 kW) in the offshore purse seine fishery in Quang Tri province, Vietnam. The fishing efficiency of the purse seine fishing boats using LED lamps has increased 1.58 times in catch rate than MH lights, although the energy consumption of LED lamp is 4 times smaller. Fuel consumption of boats per trip using LED lamps was one third of that using MH lights. The use of LED reduced the radiation spectrum, especially the intense UV radiation which negatively affects the health of fishermen. This study also showed the potential of CO_2 emission reduction up to 1.09 tons of CO_2 per trip per boat from the use of LED lamps in the offshore purse seine fishing boats.

1. Introduction

Fishing with artificial light has become one of the most advanced, efficient, and successful methods for catching commercially important species on an industrialized scale (Nguyen & Winger, 2019). Light is used to detect, attract, or repel fish to increase in gear selectivity. Fluorescent, halogen, and metal halide (MH) lights are commonly used to detect and gather fish in inland and coastal water because of their high luminescent efficiency (An, 2013; Solomon & Ahmed, 2016). During the last few decades, light emitting diode (LED) technology provides maximum illumination power combined with high energy efficiency, longer lifespan light bulbs, lower cost, better chromatic performance, and reduced environmental impact compared to other lighting technology. The use of LED technology has now spread to large commercial fisheries across a range of target species in many countries around the world (Yeh et al., 2014; Nguyen & Tran, 2015; Ortiz et al., 2016; An et al., 2017; Nguyen et al., 2017, 2021).

Vietnam currently has 100,000 fishing boats, of which there are more than 6000 purse seine fish offshore. However, the catch of purse seine accounts for 16%–22% of the total catch (Hassan & Latun, 2016). The purse seine fishery sector has become a major commodity-producing economic sector which actively contributes to Vietnam's international economic integration. The sector contributes to the transformation of the agricultural and rural economy, poverty alleviation, employment of more than 5 million workers, and the improvement of the material and spiritual life of fishermen (DCFRP, 2020). The Vietnamese purse seine fishery sector operates year-round, except during full moon periods when the conditions are less favorable for light fishing (Nguyen et al., 2021; Nguyen & Nguyen, 2011).

Of the total number of 2800 fishing vessels with a total capacity of 69,480 Horsepower (HP), in Quang Tri province, Central Vietnam, 176 purse seine fish offshore (DCFRP, 2020) use fluorescent tubes and MH lights requiring high electric power (Nguyen & Nguyen, 2011; Nguyen & Tran, 2015).

According to the Statistics Department of Quang Tri province, in November 2017, the fishery produced 1999 tons (1760 tons of fish, 13 tons of shrimp, 226 tons of other aquatic products). The total fishing output in 11 months in 2017 reached 21,958 tons, increased by 56.31%

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compared to the same period in 2016. To improve the catch of offshore fishing, Quang Tri province has many directions and policies to support fishermen, especially aiming at the application of scientific and technological advances to production.

In 2019, thanks to the help of the New Energy and Industrial Technology Development Organization of Japan (NEDO), the provincial government implemented a project to save energy and improve work efficiency by installing special LED equipment for offshore fishing boats in Quang Tri province. The project has equipped nearly 1800 LED lamps replacing MH lights for 40 offshore purse seine fishing boats in the coastal districts (DCFRP, 2020). Many studies have evaluated the use of artificial light in commercial fishing in term of catch rate, fuel consumption, and CO_2 emissions. However, little knowledge exists on the radiation spectrum of LED lamps in the purse seine fishing in Vietnam. This paper provides scientific information on the effectiveness of LED lamps in a commercial purse seine fishery, and a discussion on potential solutions minimizing the negative effects of using MH lights.

2. Materials and methods

2.1. Source of the purse seine fishing boats

This study was conducted in six purse seine fishing boats of fishermen measuring 18.5 m × 5.5 m × 2.8 m with a 410 HP engine. Three purse seine fishing boats used LED lamps (0.196 kW), and three comparative purse seine fishing boats used MH lights (1 kW). A 45 HP Yanmar-3SMGGE engine and STC-40KW generator were used to power the fishing lamps, which had separate fuel tanks and gauges that measured fuel consumption. The purse seine of all six fishing boats was 640 m long and 150 m deep, with stretched mesh sizes in the wing and bunt measuring 80 mm and 21 mm, respectively.

Three purse seine fishing boats were equipped with 52 white rectangular-shaped LED lamps (Stanley, Belgium) (196 W each x 52 lamps = 10,192 W) (Table 1). MH lights (Phillips, Japan) which consisted of 40 light units (1000 W each x 40 light units = 40,000 W) were used in three comparative purse seine fishing boats (Table 1). The MH lights were distributed with equal numbers on the starboard and port sides of the vessel placed in parallel with the vessel's existing light system. The LED lamps were installed at an angle of approximately 10° toward the water's surface. All six purse seine fishing boats carried out their fishing activity at the same fishing ground.

The fishing experiments were conducted from April 14 to May 22, 2021, with 10 days break each month (from 12th to 22nd of the lunar month) to avoid low catch rates during the full moon phases, as is typical for the Quang Tri purse seine fishery (DCRF, 2020).

2.2. Fishing ground

Fishing experiments were conducted in 3 fishing trips (five days per trip) during the annual fishing, in the offshore water from Hoang Sa area to the Gulf of Tonkin approximately 25 nautical miles directly east from the port of Cua Viet, Quang Tri province (from 16 to 24′58″N108-42′39″E to offshore). The period of the first, second and third trip were from April 14th to April 20th, from May 2nd to May 6th, and from May 16th to May 20th, respectively.

Table 1
Characteristics of the purse seine fishing boats using different lights.

Parameter	The purse seine fishing boats using LED lamps	The purse seine fishing boats using MH lights
Number of lights in a boat	52	40
Power of one light (W)	196	1000
Lighting time per night (hours)	8	8
Time for a fishing trip (days)	5	5
Total power of light source (kW/boat)	10.192	40

2.3. Spectrographic analysis of LED lamps and MH lights

The indicators of luminescence spectrum, the radiation spectrum, CIE chromaticity coordinates, correlated color temperature (CCT) have been carried out at the laboratory of Rang Dong Light Source & Vacuum Flask Joint Stock Company, on the measurement system: 1.4-TQ-R&D (Rang Dong Co., Vietnam), with the sample measurement conditions as follows: temperature at 25.6 °C, wavelength measurement ranging from 380 to 780 nm, and scanning speed at 20 ms.

2.4. Calculation of fuel consumption, catch rate, and the ratio of species

The fuel consumption and catch rate were recorded onboard the vessel on survey sheets, including departure and arrival times, lighting start and end times, and fishing positions and depths. Upon the retrieval of purse seines, all catches were sorted to the species level, and the catch was recorded in number of baskets of 20 kg. The proportion of species of each catch was calculted as the ratio of species (percentage of species in a total catch amount).

After 3 fishing trips, a comparison table including species composition and total catch, and fuel consumption for each fishing trip of boats using LED lams and comparison boats was provided.

2.5. Statistical analysis

The fishing trips took place over a 2-month period in the same fishing ground. One set per night per boat was deployed and the catch rate was different in each set. The time of each set was 8 h, thus, we consider there was a minimum of any spatial or time of day effects on catch. There were totally 90 sets observed.

The catches of species per set per boat (dependent variables) were compared between light treatments (LED lamps or MH lights) and between trips by multiple linear regression. The used regression equations have the form

$$Y = a_0 + a_1 \cdot LED + a_2 \cdot Trip1 + a_3 \cdot Trip3 + a_4 \cdot LED\_Trip1 + a_5 \cdot LED\_Trip3$$

Where Y is the dependent variable represented the catch of a specified specie per set per boat, the binary independent variables are defined as follows:

LED = 1 if LED lambs were used,
= 0 if MH lights were used;
Trip1 = 1 if the set was done during April 14th to April 20th (Trip 1),
= 0 otherwise;
Trip3 = 1 if the set was done during May 16th to May 20th (Trip 3),
= 0 otherwise;
LED_Trip1 = LED * Trip1 = 1 if LED-lambs were used & the set was done during April 14th to April 20th (Trip 1),
= 0 otherwise;
LED_Trip3 = LED * Trip3 = 1 if LED lambs were used & the set was done during May 16th to May 20th (Trip 3),
= 0 otherwise.

Among the independent variables, LED_Trip1 and LED_Trip3 represent the interaction effect of the two factors light treatment and trip period on the catches. The intercept (constant) a_0 interprets the average value of the dependent variable Y corresponding to the values 0 of all independent variables. The coefficient a_1 indicates the surplus of the average catch per set done by boats with LED lamps upon the average catch per set done by boats with MH lamps. The coefficients a_2 and a_3 show the differences of the average catch per set done during the first trip (April 14th to April 20th) and the third trip (May 16th to May 20th) comparing to the average catch per set done during the second trip (May 2nd to May 6th). In the regression models, the interaction effect of the two factors, light treatment and trip period, on the average catches is exposed by the coefficients a_4 and a_5. A coefficient is significant if its p-value is less than 0.05.

Due to the samples are small, the fuel consumption per trip of two groups of the purse seine fishing boats using LED lamps (9 trips) and the purse seine fishing boats using MH lights (9 trips) was compared using the nonparametric Mann - Whitney test at the significance level of 0.05.

All data analyses were performed by using the SPSS 20.0 (SPSS Inc., Chicago, IL).

3. Results

3.1. Spectral characteristics of LED lamps and MH lights in purse seine fishing boats

The radiation spectrum and the CIE color space chromaticity diagram with wavelengths in nanometers (The International Commission on Illumination, usually abbreviated CIE for its French name, Commission internationale de l'éclairage) of the LED lamps and MH light are presented in Fig. 1 and Fig. 2. The spectrum of LED lamps is a cluster form with two wide bands. The first spectrum was in the blue region with the wavelength ranging from 380 to 480 nm (maximum of 450 nm) and a second-wide band was in the green zone with the wavelength ranging from 480 to 780 nm (maximum of 550 nm) (Fig. 1). Meanwhile, the radiation spectrum of MH lights disintegrated to narrow lines with maximum radiation was in an orange zone with the maximum wavelength ranging of 590 nm (Fig. 2). In the wavelength's range of ultraviolet radiation (380–420 nm), the radiation spectrum of LED lamps was very weak at nearly zero (Fig. 1). The radiation spectrum of MH lights showed peak of narrow lines with strong intensity of 0.3 (Fig. 2).

The CIE chromaticity coordinate of the LED lamp coordinate gave a value of x = 0.3447, y = 0.3553, and CCT = 5000 K located at the radiation balance point in the CIE chromaticity coordinate, emitting white radiation. Meanwhile, the chromaticity coordinate of MH lights had the value of x = 0.4301 and y = 0.3920, and CCT = 3,017 K which was in the yellow-white radiation area, and could be seen by naked eyes.

3.2. Composition and the ratio of fish species caught

Over 5 nights of fishing, the average catch of the purse seine fishing boats using LED lamps and the purse seine fishing boats using MH lights were 33.414 ± 0.02 t/boat, and 21.155 ± 0.015 t/boat, respectively. The catch of the purse seine fishing boats using LED lamps was 1.58 times significantly higher than the comparative purse seine fishing boats using MH light ($P = 0.01$).

The ratio of economic species caught by LED lamps or MH lights was similar, especially the main fishing species of *Rastrelliger kanagurta* ($P = 0.2$)*, Thunnus albacares* ($P = 0.4$)*,* and *Trachurus saurus* ($P = 0.7$). There is no significant difference between the ratio of non-target species of the purse seine fishing boat using LED lamps or using MH lights ($P = 0.1$) (Fig. 3). For the purse seine fishing boats using LED lamps, the *Decapterus macrosoma* catch accounted for the largest ratio (44%), followed by *Rastrelliger kanagurt* (22%), *Thunnus albacares* (14%), *Trachurus saurus* (9%), and non-target species (11%).

Similarly, for the MH light purse seine fishing boats, *D. macrosoma* still accounted for the largest proportion (35%), followed by *Rastrelliger anagurta* (25%), *Thunnus albacares*, and *Trachurus saurus* all made up 15% and non-target species (10%) (Fig. 3). *D. macrosoma* was predominant and significantly higher ($P = 0.01$) when using LED lamps compared to MH lights.

Multiple linear regression models (Table 2) showed the average catch per set of *Thunnus albacares*, *Decapterus macrosoma*, *Rastrelliger anagurta*, *Trachurus saurus,* and non target species of the boats using MH lights (LED = 0) for the second trip (Trip = 0, Trip 3 = 0) were 235.267, 506.133, 407.800, 230.333, 188.067 kg per single set, respectively.

The catch of *T. albacares*, *D. macrosoma*, *R. anagurta*, and non target species by using LED lights increased 171.400, 669.667, 199.533, and 22.267 kg per single set, respectively (Table 2). Although the catch of *T. saurus* decreased 10.333 kg per single set, however, there was no significant difference in catch rates of this species between trip 1 and trip 2 ($P = 0.324$).

The using LED lamps instead of MH lights increased catches of *T. albacares*, *D. macrosoma*, *R. anagurta*, and non target species 171.400, 669.667, 199.533, and 22.267 kg per single set, respectively. The catch of *T. albacares*, *R. anagurta*, *T. saurus,* and non target species for the first trip (Trip1 = 1) were 96.133, 161.867, 25.600, 61.533 kg per set (respectively) lower than the catch of those for the second trip (Trip1 =

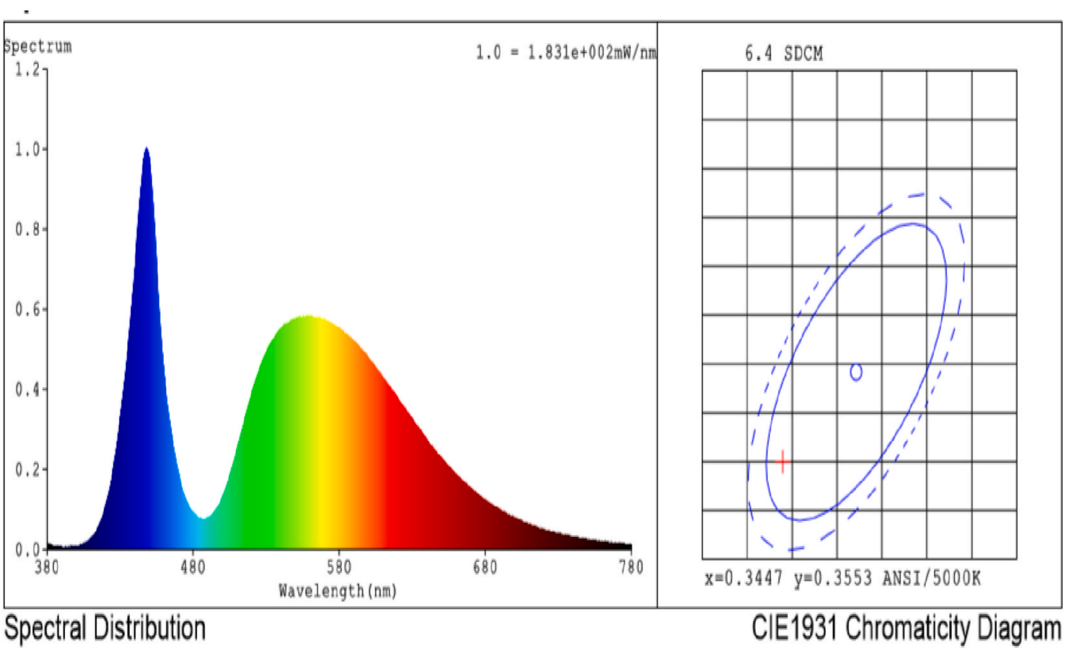

Fig. 1. Spectrum of radiation and CIE color space chromaticity coordinates of LED lamps.

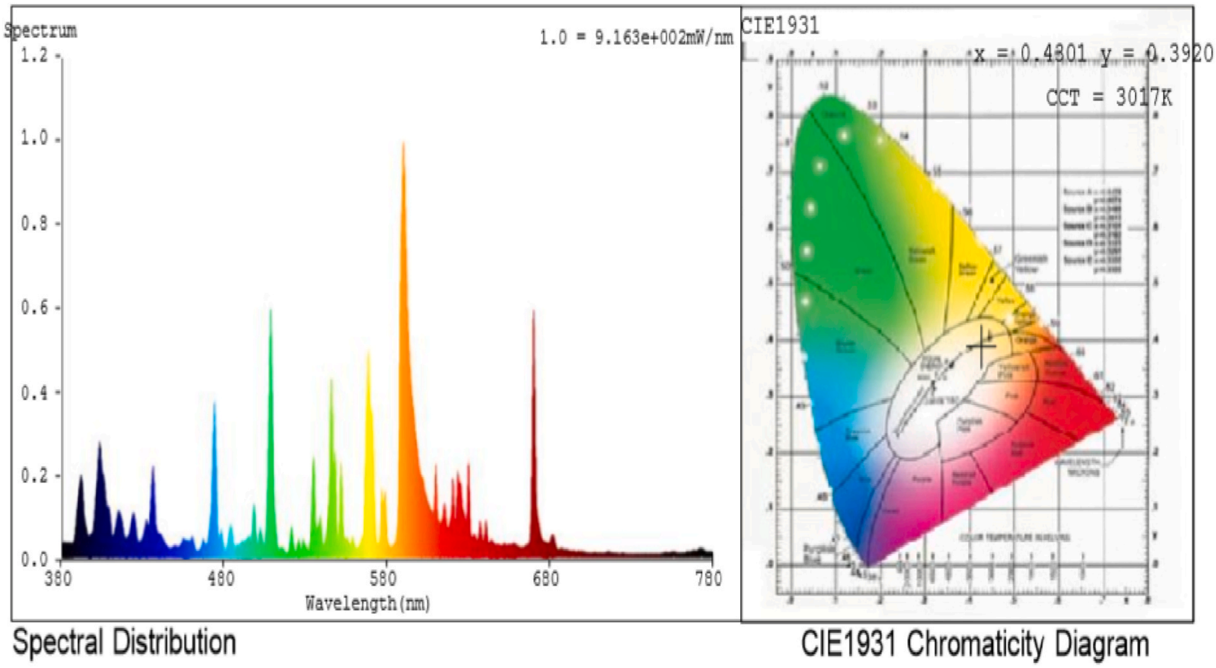

Fig. 2. Spectrum of radiation and CIE color space chromaticity coordinates of MH lights.

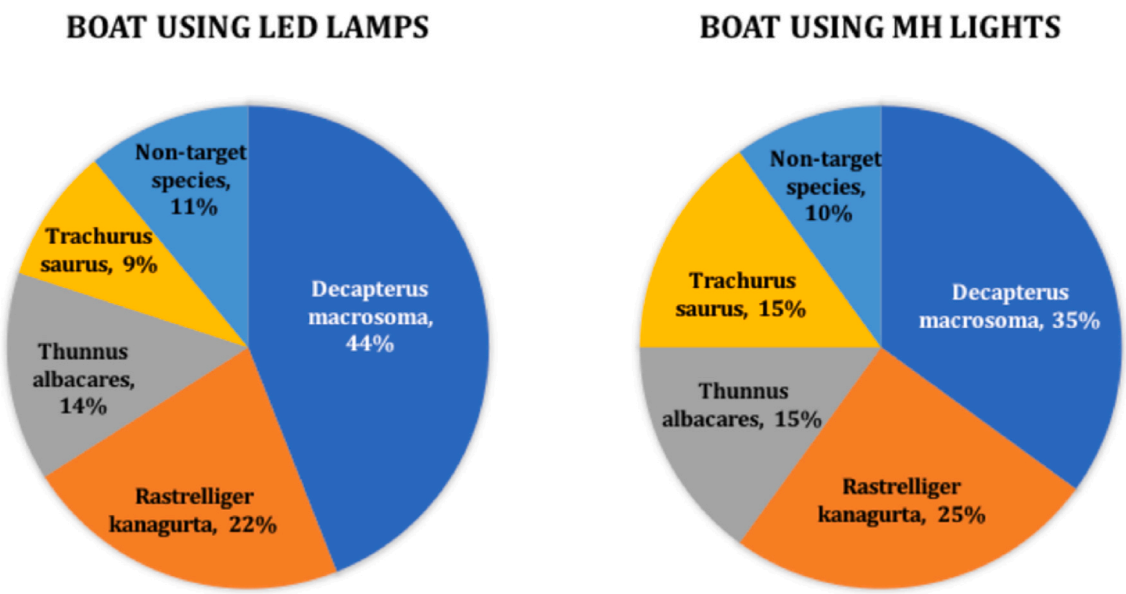

Fig. 3. Percentage of species catch per boat per trip of the group of 3 purse seine fishing boats using LED lamps or using MH lights.

Table 2
Regression models of the influences of light treatments and trips on species catches.

Regression model	*Thunnus albacares*	*Decapterus macrosoma*	*Rastrelliger kanagurta*	*Trachurus saurus*	Non target species
(Constant)	235.267***	506.133***	407.800***	230.333***	188.067***
LED	171.400***	669.667***	199.533***	−10.333	22.267*
Trip1	−96.133***	5.000	−161.867***	−25.600*	−61.533***
Trip3	33.867**	−15.800	6.400	−11.267	−47.400***
LED_Trip1	−87.133***	−180.200***	204.533***	11.133	79.533***
LED_Trip3	−151.600***	−371.667***	−10.067	−6.733	147.600***

Note: *** = ($P < 0.001$); ** = ($P < 0.01$); * = ($P < 0.05$).

0 and Trip3 = 0). The catch of *T. albacares* for the third trip (Trip3 = 1) was 33.867 kg per set higher than that for the second trip. The interaction of light treatments and trips significantly increased the effectiveness of LED lambs for catching *T. albacares, D. macrosoma, R. anagurta,* and non target species. During the first trip, LEDs increased the catch of *T. albacares*, *D. macrosoma, R. anagurta,* and non target species by 171.400–87.133 = 84.267 kg, 669.667–180.200 = 489.467 kg, 407.800 + 204.533 = 612.333 kg, and 22.267 + 79.533 = 101.800 kg per set, respectively, compared to 171.400–151.600 = 19.800 kg, 669.667–371.667 = 298.000 kg, 199.533–10.067 = 189.466 kg, and 22.267 + 147.600 = 169.867 kg per set for those species caught during the third trip.

3.3. Fuel consumption of the purse seine fishing boats using LED lamps and the purse seine fishing boats using MH lights

Fuel consumption of the purse seine fishing boats using MH lights and ones using LED lamps is determined based on the fuel consumption norms of auxiliary engines at the dynamo serving for MH and LED lighting. The total fuel (oil) consumption for each sea-fishing trips of the purse seine fishing boats using LED lamps is 504 L, while that of the purse seine fishing boats using MH light is up to 1631 L. The fuel consumption and cost of the purse seine fishing boats using LED lamps is only one third of the purse seine fishing boats using MH lights ($P = 0.01$) (Table 3).

4. Discussion

Fishing with artificial lights (surface light) to attract and accumulate fish (Nguyen & Winger, 2019) prior to harvest has a long history in many parts of the world (Sokimi & Beverly, 2010; An, 2013).

According to the International Lighting Vocabulary, light is defined as any radiation capable of causing a visual sensation directly. Light or visible light, which is responsible for the sense of sight, is electromagnetic radiation visible to the human eye (CIE, 1987; Kumar, 2008). Visible light has wavelength in the range of about 380 nm to about 740 nm (Choudhury, 2014).

Light emitting diode (LED) lamps used in this study have a wavelength ranging from 380 to 480 nm (peak wavelength of 450 nm) (Fig. 1), which is in the peak absorbance 400 nm–494 nm of the water in the area, where a majority of deep-water species fishing occurs (Nguyen & Winger, 2019; Nguyen et al., 2021). By contrast, the radiation spectrum and CIE color space chromaticity coordinates of MH lights have the peak of wavelength ranging of 590 nm (Fig. 2). The color (i.e., wavelength) produced by an artificial light can strongly affect behavioral tendencies to aggregate in marine organisms (Jeong et al., 2013; Matsui et al., 2016; Kehayias et al., 2016). The CIE color space chromaticity coordinates of LED lamps used in this study demonstrated a suitable light for fishing gear.

The illumination intensity produced by artificial light also strongly affects behavioral tendencies to aggregate in fish (Bradburn & Keller, 2015; Matsui et al., 2016) and demonstrates that increasing intensity (kW) of surface-mounted lights can increase fishing gear efficiency (Nguyen & Winger, 2019). However, in this study, the fishing productivity of the group of the purse seine fishing boats using LED lamps (10.2 kW/boat) were 1.58 times significantly higher than that of the group using MH lights (40 kW/boat). The ratio of species catch of two groups were similar in the main fishing species such as *Decapterus macrosoma, Rastrelliger kanagurta, Thunnus albacares,* and *Trachurus saurus* (Fig. 3). These results showed the clear differences in different lights and the ratio of species catch were not affected by the lamp power in offshore seine fishing. Another study also presented that when using lights with different power of 1.6; 3.2; 4.6; and 6.4 kW did not affect to composition of pelagic species of offshore seine fishing (Nguyen & Nguyen, 2011). The statistical results showed the ratio of non target species was not remarkably changed between different light uses. It proved that LED lamps don't increase the catch of non-target species. This would be a positive outcome of LED lamps. The linear regression model showed significant increase in the catch of *T. albacares, D. macrosoma, R. anagurta* for the second trip (from May 2nd to May 6th) compared to other trips. Based on the lunar phase, the second trip was conducted one week after full moon, while the first and third trip were happened on one week before full moon. We speculated that catch amount tended to increase from the full moon to the new moon, and an opposite tendency was shown from the new moon to the full moon. According to Matsushita and Yamashita (2012), lunar phase may direct influence of light in the environment and to the internal rhythm of schooling fish. However, our results have just analyzed the catch data in limited time period, so the influence of the lunar phase to catch should be further investigated.

The data of this study also showed the increase of ratio of *D. macrosoma* instead of *R. kanagurta*, and *D. macrosoma*, a predominately pelagic schooling species is targeted by the purse seine fisheries (Jamal et al., 2021). The using LED lamps possibly attracted this pelagic schooling species. *D. macrosoma* is an economically important species in Central Vietnam. Increasing the catch of this species results in the improvement of local fishermen's income.

The correlated color temperature (CCT) of the light sources are expressed by the temperature of the black-body radiator whose color is closest to that of the light source (Choudhury, 2014). Light from warm-white light sources appears yellow-white and will have CCT between about 2700 K and 3500 K. Cool-white light is seen as blue-white with CCTs ranging from 4500 K to 7500 K. Light sources with CCTs in the middle range (3500–4500 K) are described as neutral-white. In this study, the results of the CCT analysis of two kinds of lights showed that the CCT value of LED lamp was 5000 K, corresponding to "daylight", and the CCT value of MH light was 3017 K, corresponding to "warm white light" in human visual perception (Choudhury, 2014). LED lamp is suitable for the lighting industry, which formally refers to warm-white (3000 K), white (3500 K), cool-white (4000–4500 K), and daylight (6500 K) (ANSI, 2001). Ultraviolet radiation is known to affect human health, causing skin diseases and cancer during long-term exposure (Choudhury, 2014). Taken together, this shows that LED lamps had more advantages and were user-friendly than MH lights.

Fuel consumption for using surface light accounts for as much as 40–60% of the total operational cost in the offshore purse seine fishing (Matsushita et al., 2012; Nguyen & Tran, 2015; Matsui et al., 2016, An et al., 2017). In this study, by replacing 1000 W MH lights with specialized LED lamps for fishing, the electric power consumption of the purse seine fishing boats using LED lamps was only one third compared to the purse seine fishing boats using MH lights, leading to reduce oil consumption to 69.1%. When combining LED lamps and MH lights for night fishing, Nguyen et al. (2021) showed fuel consumption reduced to 37.9% compared to using MH lights alone. This clearly showed the advantages of using LED lamps in fishing. Furthermore, the catch rate of the hairtail (*Trichiurus lepturus*) of vessels using only 21.6 kW of LED lamps was similar to that of vessels equipped with higher power (45–84 kW) MH lights (An et al., 2017), and even increased the catch rate of anchovy *(Stolephorus* sp.) up to 30%, while fuel consumption decreased by 35%, compared to similar trials with compact fluorescent light (Susanto et al., 2017). LED lamps show high chromatic performance with lower energy consumption than MH lights and significantly reduced fuel consumption by vessels (An et al., 2017; Matsushita et al.,

Table 3
Oil consumption and cost per trip per the purse seine fishing boat using LED lamps or MH lights (0.69 USD/L).

Fuel cost information	The purse seine fishing boat using LED lamps	The purse seine fishing boat using MH lights
Oil consumption per trips (L)	504 ± 3	1, 631 ± 7
Total cost (USD)	347.76	1125.40

2012; Mills et al., 2014; Nguyen & Tran, 2015; Susanto et al., 2017). The use of energy-saving LED lamps for fishing is therefore recommended (An & Jeong, 2011, 2012; Choi, 2006; Jeong et al., 2013; Masuda et al., 2017; Matsushita et al., 2012). Moreover, according to An et al. (2017), burning 1 kg of diesel for operating the generators onboard the vessel produces 3.19 kg CO_2. Using LED lamps will contribute to reduce fuel consumption and CO_2 emissions.

Fishing with artificial light requires electricity for lights, which results in the unintended by-product of emissions of CO_2, a harmful greenhouse gas (Nguyen & Winger, 2019). In this study, when we calculated the reduction of CO_2 emissions of using LED lamps with the scenario: (i) vessels harvesting pelagic fish using 52 LED lamps (10.2 kW), and (ii) purse seine fishing vessels equipped with 40 MH lights (40 kW), the amount of greenhouse gas emission reduction is determined according to the formula (HCMEPD, 2017): $ER_y = BE_y - PE_y$

Where: ER_y was the reduction of greenhouse gas emissions of the LED model compared to the MH lights. BE_y is the baseline emission of MH lights in the yth year; PE_y is the baseline emission of LED lamps in the yth year.

On average, each purse seine fishing boat using MH lights has about 40 MH lights, with an average capacity of 1000 W/bulb. We assume an average of 8 h of lighting per night, and five days per trip. The total number of lighting hours of a sea-fishing trip is calculated as follows: 8 (hours/day) × 5 (day) = 40 (hours per boat per trip). If 40 MH bulbs are replaced with 52 dedicated 196 W LED/bulb, the reduction in the CO_2 reduction is calculated as 1.09 tons of CO_2/trip. In 6 months of sea-fishing trips per year, the CO_2 emissions would fall by more than 39.24 tons of CO_2/year. If all 176 purse seine fishing boats in Quang Tri province used LED lamp for fishing, the CO_2 emissions would have decreased by over 6.9 thousand tons of CO_2/year. That has great significance in contributing to environmental protection and climate change mitigation. It is an important point of LED lamp in the purse seine fishing in contribution to reduce the global warming.

In Quang Tri province, small scale fisheries are the main livelihood activity of local fishermen. Surface light fishing provides the food security and employment, however, investment in lighting equipment is a big challenge for local people. This study showed the advantage of using LED lamps in the purse seine fishing, in term of reducing fuel consumption and increasing the catch rate, leading to cost saving for fishing. However, until now only 40 of 176 offshore purse seine boats have replaced MH lights by LED lamps in Quang Tri province. Based on the scientific data showing the advantage of using LED lamps in the purse seine fishing boats, the government should develop suitable policies or provide incentives supporting local people to replace the MH lights by LED lamps in their fishing activity.

5. Conclusion

This study showed purse seine fishing boat using LED lamps have many outstanding advantages such as radiation spectrum, CIE chromaticity coordinates, and the correlated color temperature, which are very close to daylight compared to MH lights. The use of LED lamps decreases the oil consumption and increases the catch amount. Replacing MH light in the purse seine fishing boats would reduce the CO_2 emission.

Declaration of competing Interest

All authors approved the manuscript, this submission and declared no known conflicts of interest associated with this publication.

CRediT authorship contribution statement

Nguyen Dang Nhat: Conceptualization, Funding acquisition, Methodology, Investigation, Writing – original draft. **Do Thanh Tien:** Investigation, Data curation, Formal analysis, Writing – original draft. **Truong Van Dan:** Investigation, Resources. **Nguyen Duy Quynh Tram:** Investigation, Resources, Data curation. **Nguyen Quang Lich:** Investigation, Data curation. **Ho Dang Phuc:** Data curation, Formal analysis, Writing – review & editing. **Nguyen Ngoc Phuoc:** Conceptualization, Methodology, Investigation, Formal analysis, Writing – review & editing.

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