Application of fish-attracting lights, at surface and underwater, in raft fishing in Manado Bay, North Sulawesi, Indonesia

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Abstract. This study aimed to analyze the catch composition, the effectivity of the raft facilitated with underwater LED light, and the use of surface electrical light in fishing operations in Manado Bay. It was carried out for 14 trips from May 23rd to June 5th, 2022 using using two types of handlines (multi-hook handline and squid-handline), purse seine, and gill net. The catch was dominated by yellow-stripe scad (*Selaroides leptolepis*), moonfish (*Lampris guttatus*), trevally (*Caranx* sp.), mackerel tuna (*Euthynnus affinis*) and squids (*Loligo* sp.). The use of underwater LED light gave a higher catch (61.29%) than that of surface electrical light (38.71%). The highest effectivity was recorded in the purse seine (50.81%), followed by handline (29.45%), and then net (19.74%).
Key Words: catch, handline, net, purse seine.

Introduction. The fishermen community in Manado Bay is a group of traditional fishermen who use nets, handline, and a small fish aggregating device (FAD) facilitated with electrical lights or gasoline lamps in their fishing operations. Every fishing activity is basically intended to obtain as many fish as possible by using an environmentally-friendly fishing technology and following the fisheries regulations (FAO 2003).

One of the fish aggregating technologies is to take advantage of the fish's attraction to the light (Thenu et al 2013). Purbayanto et al (2010) reported that fish response to light stimulation depends on the light penetration into the water and the light wavelength. Red light has the longest wavelength and the shortest penetrability into the water, followed by orange, yellow, blue, and violet. Light wavelength and the distance of light penetration into the water have a strong correlation as mentioned in Lambert-Beer Law that the light intensity in the water will exponentially decrease with depth and particle concentration (Halliday et al 2013). Light also affects the fish's behavior in their activities, such as feeding, spawning, etc. (Anras et al 1997). The use of artificial light in fishing operations can highly influence mean fish catches and help reduce bycatch (Nguyen & Winger 2019). This study focuses on the effectiveness of the underwater LED light-assisted raft on the fish catches in Manado Bay, North Sulawesi.

Material and Method. The fishing ground was geographically positioned at 1°30'483" N and 124°45'461" E (Figure 1). Fishing activities were operated from 18.00 to 03.00 on May 23 to June 5, 2022, covering 2 moon phases, quarter 3 (KW3), and new moon (NM) (Table 1).

The raft was 3 m x 4 m sized set with 16-watt white light and added with 14-watt yellow and red colored LED lights. The underwater LED light was located at 3-5 m depth. The yellow light was first turned on to attract and gather fish to the catchable area. When the fish school gathered under the raft, the color was changed to red light to concentrate and calm them down in the catchable area. The use of surface light started at 6.00 pm to 6.00 am, then the light was wrapped with a red cloth around midnight or 02.00 am after the fish had been gathered around the raft.

The treatment of two types of light was done alternatively every two days for 14 days from May 23 to June 5, 2022, in 2 moon phases, namely quarter 3 (KW 3) for 1st to 3rd trips and new moon (NM) for 7th to 14th trips. The underwater LED light was used on 8 fishing trips, while the sea surface light was applied on 6 trips (Table 1).

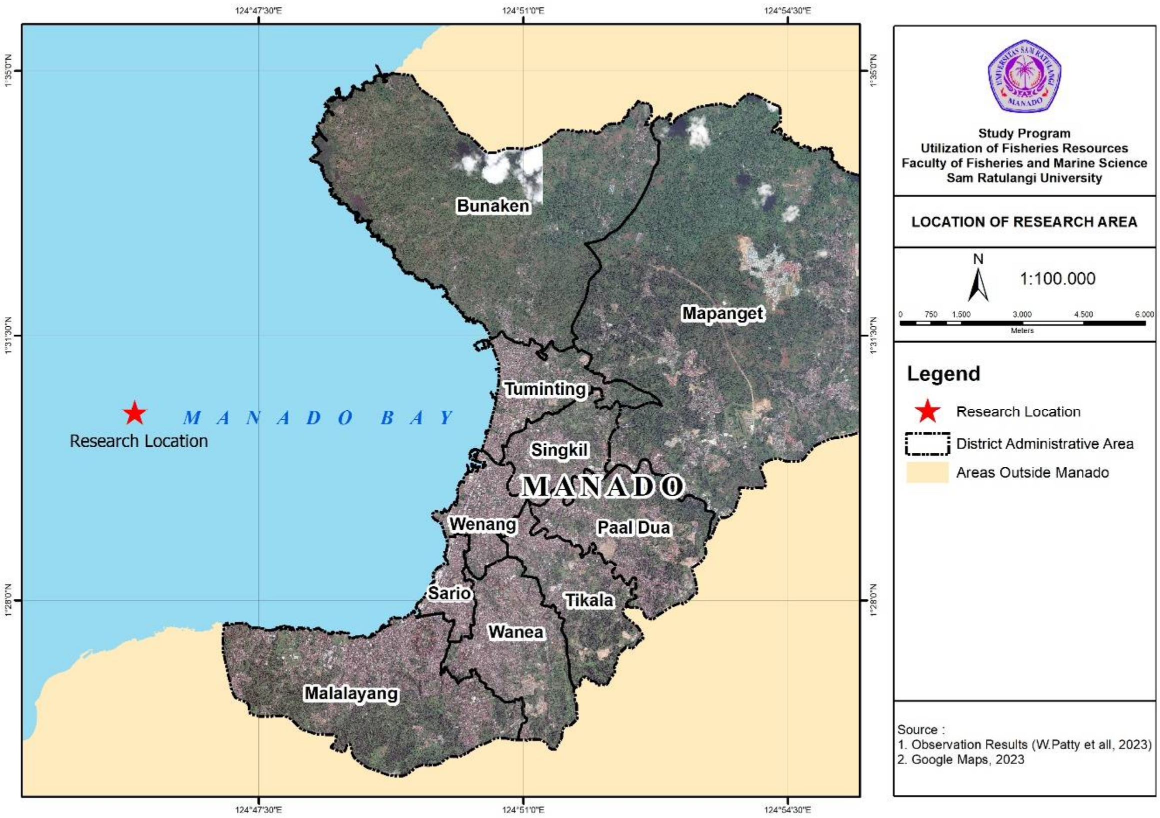

Figure 1. Fishing ground.

Table 1

Observation time and light treatments

Trip	*Date*	*Moon phase*	*Treatment*
1	May 23, 22	KW 3	Underwater light
2	May 24, 22	KW 3	Underwater light
3	May 25, 22	KW 3	Sea surface light
4	May 26, 22	KW 3	Sea surface light
5	May 27, 22	KW 3	Underwater light
6	May 28, 22	KW 3	Underwater light
7	May 29, 22	NM	Sea surface light
8	May 30, 22	NM	Sea surface light
9	May 31, 22	NM	Underwater light
10	June 1, 22	NM	Underwater light
11	June 2, 22	NM	Sea surface light
12	June 3, 22	NM	Sea surface light
13	June 4, 22	NM	Underwater light
14	June 5, 22	NM	Underwater light

Notes: KW 3 = quarter 3, NM = new moon.

There were 4 types of fishing gears used in this study, multiple hook vertical hand-line (5 units) using 14-numbered hooks, a 15-GT purse seiner, a 2-inch-meshed gill net (1 unit), and a squid hand-line (2 units), respectively. Hand-line fishing was operated since the underwater LED or surface light has been turned on. The gill net and the purse seine were operated at midnight or 03.00 am after the fish had gathered under the raft.

Each fishing operation was supported with sea surface lights or underwater LED lights. The fish catches of each fishing operation were recorded with treatments. The effectiveness value was calculated from the relative number of catches at the light-type application and fishing gear in a fishing operation as follows:

1. Effectiveness of light-type application:

$$E_i = \frac{\sum_{j=1}^{n} h_i}{\sum_{i=1}^{m} \sum_{j=1}^{n} h_{ij}}$$

2. Effectiveness of fishing gear used with light type:

$$E_{ij} = \frac{h_{ij}}{\sum_{j=1}^{n} h_i}$$

where: E_i = effectiveness of raft with *i* light (i = 1 with surface light and i = 2 with the addition of an underwater LED light, E_{ij} = effectiveness of *j* fishing gear (j = 1 is handline, j = 2 is purse seine, and j = 3 is gill net) on the raft with *i* light (i = 1 with surface light and i = 2 is the addition of underwater LED light, h_j = catch with *j* fishing gear (j = 1 is handline, j = 2 is purse seine, and j = 3 is gillnet), h_i = catch with *i* light application, h_{ij} = raft catch with *i* light application in *j* fishing gear (j = 1 is handline, j = 2 is purse seine, and j = 3 is gill net).

Results and Discussion. During the study, there were 4 fish species caught, yellow-striped scad (*Selaroides leptolepis*), mackerel tuna (*Euthynnus affinis*), big eye trevally (*Caranx* sp.), moonfish (*Lampris guttatus*), and squids (*Loligo* sp.). The size range was 18-25 cm long for *S. leptolepsis*, 18-20 cm long for *Caranx* sp., 20-22 cm long for *E. affinis*, 15-18 cm long for *L. guttatus*, and 15-27 cm long for *Loligo* sp., respectively.

Total fish catch during KW 3 (trips 1-6) varied from 335 to 680 ind trip^{-1}, and this number was relatively lower than that during the NM operations (trips 7-14), 260 to 960 ind trip^{-1} (Figure 2). The moon's cycle from dark to bright conditions influences the light received by the earth due to the change in the sunlight reflecting angle by the moon against the earth. The light intensity condition affects the fisheries since the fish's phototaxis is beneficial in fishing operations. In the NM period, when the water is relatively dark, the use of light to attract fish to the light source is very effective (Marchesan et al 2005). The Vietnamese purse seine fishery sector operates year-round, except during full moon periods when the conditions are less favorable for light fishing (Nguyen & Winger 2019; Nguyen et al 2021).

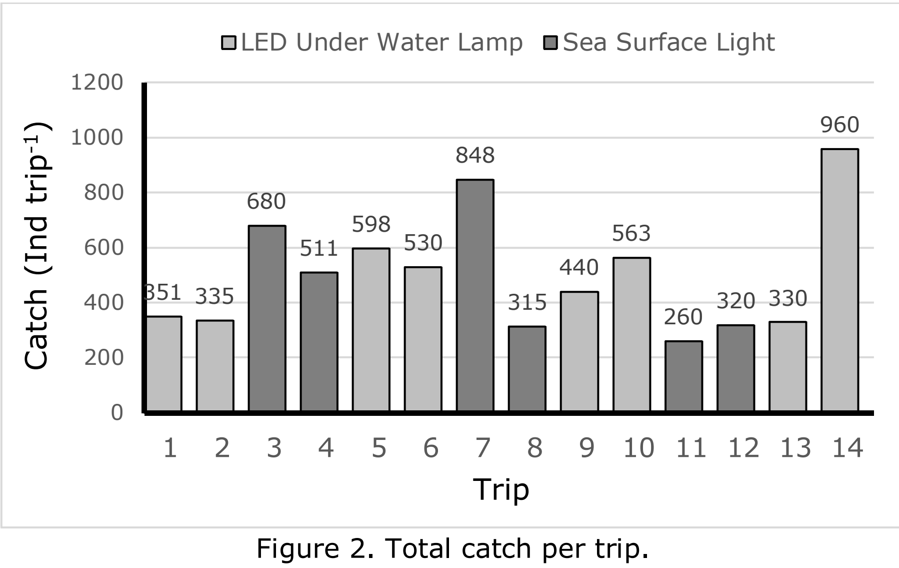

Figure 2. Total catch per trip.

The mean number of catches was relatively higher in the use of the underwater LED light than that in sea surface light, 538 ind trip^{-1} and 451 ind trip^{-1}, respectively, and the catch was dominated by *S. leptolepis*, followed by *Caranx* sp., and *L. guttatus* (Figure 3).

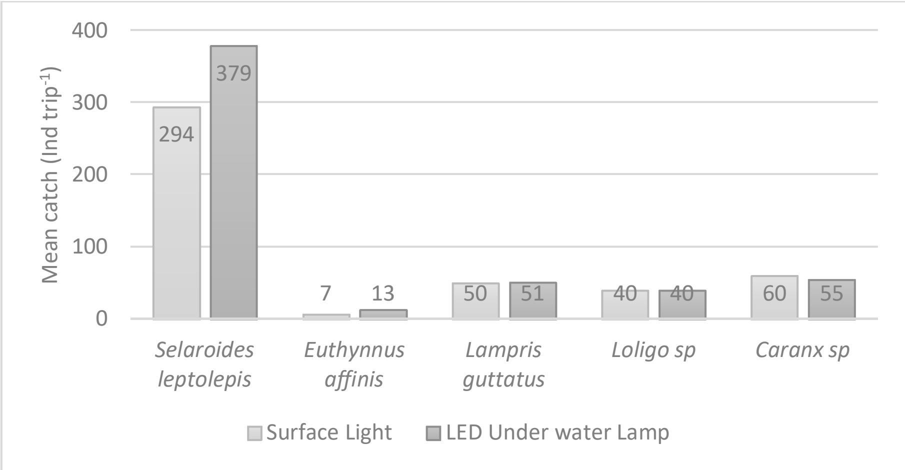

Figure 3. Mean catch with light type.

The effectivity of the raft was 61.29 for the use of the underwater LED light and 38.71 for the use of the surface electrical light (Figure 4).

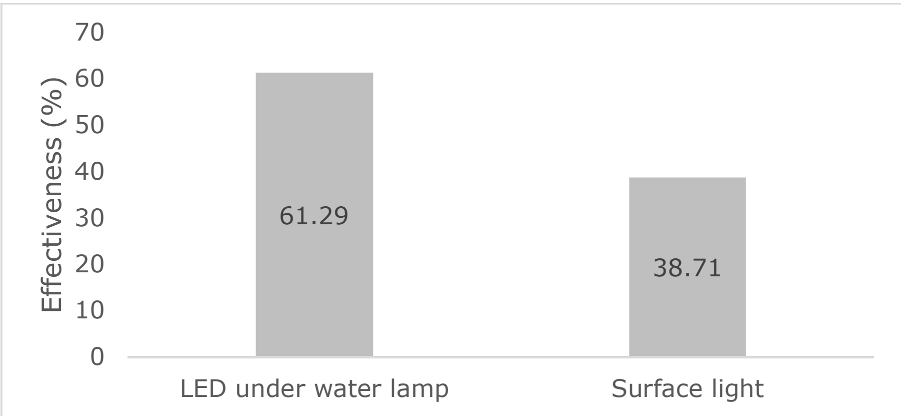

Figure 4. Effectiveness of the raft facilitated with light application.

This finding is also in agreement with Humborstad et al (2018) that cod (*Gadus morhua*) catches in Nothern Norway are 17 times higher in artificial light fishing than that without light, and the use of moderately brighter light obtains higher catch than that in low light intensity. Also, the use of the underwater light and the sea surface light in the raft in Rossenberg Strait, the Southeast Molucca Regency, showed higher catch in the fishing supported with the underwater light, but the catch is dominated by Indian mackerel *Rastrelliger kanagurta* (Notanubun & Patty 2010).

The LED light is very efficient to apply as an artificial lamp in the fish gathering process because its color and intensity highly influence the fish behavior and the retinular response (Nguyen & Winger 2019). According to Siebeck et al (2008), the light intensity and color entering the water will be responded to by the retina, in which the fish eye exposed to the light will activate the cone cells from the pigment epithelium membrane to the outer limiting membrane. The different responses of the retina could be used to measure the fish's attraction level to the light.

The dominance of scad around the light is also supported by Wisudo et al (2020) in relation to their positive phototaxis behavior. Nguyen & Winger (2019) added that pelagic fish are more attracted to green, blue, and yellow colors, with a wavelength of 494-500 mm (Munz & McFarland 1973). According to Matsushita et al (2012) and An et al (2017), LED light consumes low energy to produce a high light intensity, has longer durability, high efficiency, better chromatic performance, and lower environmental impact than traditional lighting technology.

The present study also indicated that the use of underwater light in purse seine and gill net fishing was higher than that of the surface light, but the catch in the line fishing was relatively similar in both the underwater light and the surface light (Figure 5). Mean catches in the purse seine were 299 ind $unit^{-1}$ $trip^{-1}$ for the underwater light and 203 ind $unit^{-1}$ $trip^{-1}$ for the surface light, whereas, in the gill net, it was 165 ind $unit^{-1}$ $trip^{-1}$ and 30 ind $unit^{-1}$ $trip^{-1}$, respectively.

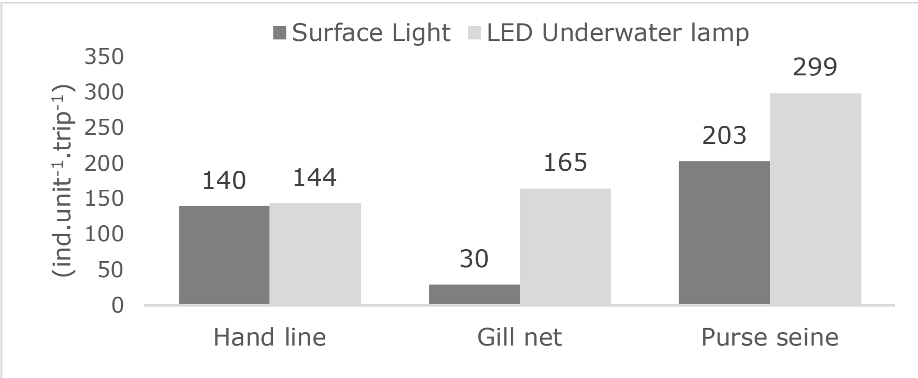

Figure 5. Mean catch with fishing gear and light type.

Based on the fishing gear used in the raft, the purse seine was more effective than the two others (Figure 6). According to Von Brand (1984), the purse seine is an effective fishing method used to capture aggregations of fish or school near the surface. Once a school of fish is located around artificial light, the fishing vessel quickly surrounds it using a long and deep net (the seine) that encircles the school. Purse seines are currently one of the best fishing gears that continue to be developed by large-scale fisheries for pelagic fishing and can be used on the high seas far from the coastline.

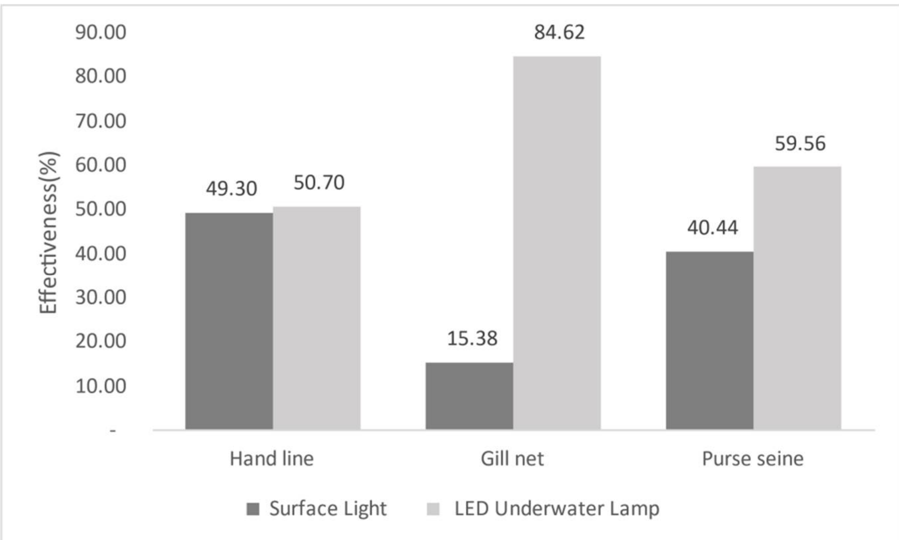

Figure 6. The effectiveness of the raft with types of fishing gears.

The effectiveness of an underwater LED light in fishing operation is relatively higher than that of the surface light. Figure 6 shows that the use of the underwater light gives the effectivity above 50%, whereas that of the surface light does below 50%, respectively. It means that better catch could be more dependent upon the light that is able to reach a wider distance to attract the fish school. It is in agreement with Shen et al (2013) that the underwater LED light has an effectivity as much as 81%. The use of an underwater light enables almost 100% of the light to enter into the water, whereas the use of surface light can reflect 70% of the light over the surface (Sukandar & Fuad 2015). The underwater light intensity highly influences the time length of the fish school to gather around the lift net (Guntur et al 2015), but the fish will maintain the distance to the light source. The hungry fish tend to approach the light sooner and are actively feeding.

Conclusions. The use of underwater LED light under the fish aggregating device in Manado Bay waters, North Sulawesi, was more effective than that of the surface light in fishing operations. The catches were dominated by yellow-stripe scad (*Selaroides* sp.), followed by moonfish (*Lampris guttatus*), big eye trevally (*Caranx* sp.), and the lowest was squids (*Loligo* sp.). The use of the underwater LED and surface lights as supporting equipment to attract fish schools in a fishing operation, particularly Manado Bay, North Sulawesi, was very feasible with an effectiveness of 50-85%.

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Conflict of interest. The authors declare that there is no conflict of interest.

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