Assessing horseshoe crab avoidance response of flicker and continuous red-light LED: Gillnets bycatch mitigation

R Rahayu1*, R W Fuah2, R I Wahju3, W Mawardi3, I Agustina1, M Arif1, S Salmarika1

1 Department of Fisheries Resource Utilization, Faculty of Marine and Fisheries, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia 
2 Department of Capture Fisheries Technology, Government College of Marine and Fisheries of Matauli, Sumatera Utara 22611, Indonesia 
3 Department of Fisheries Resource Utilization, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University, Bogor 16111, Indonesia

*Corresponding author: rosirahayu88874@gmail.com

Abstract. The horseshoe crab has the important roles as macrobenthos, but it is unfriendly for gillnets fisheries because it can damage the fishing net. The horseshoe crab is an ancient, rare, and protected animal so that the fishermen unable to utilize it, so the effort like mitigations need to be conducted like using red light LED. To avoid the learning behavior of horseshoe crab, so that the technology used is red light LED continuous then the red light led with flicker is used as a comparison. This study aims to determine the right type of red-light LED for horseshoe crab bycatch mitigation by the response pattern. The method used was a laboratory experiment. There are 20 adult horseshoe crabs used. The analysis used was descriptively comparative. The results showed that the red-light LED with flicker was most avoided by horseshoe crabs, which is 75%, while the fastest response of horseshoe crab in avoiding light was found in the light with a flicker effect of 22.97 seconds. Based on the horseshoe crab's response, it can be concluded that the red LED light flicker is better than the red LED continuous as an alternative technology for the mitigation of horseshoe crab bycatch.

1. Introduction

Horseshoe crab is an arthropod that becomes a bycatch for demersal gillnet. Bycatch horseshoe crab is a problem for gillnet fishermen, because the number of horseshoe crabs dominates compared to the main catch, namely rajungan, as a result, fishermen lose. The capture of horseshoe crabs coincides with the blue swimming crab due to the presence of the same habitat [1] that is in intertidal area [2], horseshoe crab accidentally entangled in demersal gillnet. On the body of horseshoe crabs have many thorns so that when caught [3], horseshoe crabs will be entangled to the net and very difficult to release. Therefore, fishermen are forced to tear the nets to release them [4].

The problems are the reason why research to reduce horseshoe crab bycatch is important. Initially the research was conducted by [5] using LEDs by looking at and utilizing horseshoe crab behavior that dominantly relies on visuals in daily activities. Continuous red LED light is the most likely to prevent horseshoe crabs from gillnets, as evidenced by [6] with the highest number of avoidance responses...
compared to other colors, such as green, blue and purple. The avoidance of horseshoe crabs from continuous red LEDs is due to horseshoe crab's preference for short waves rather than colours with long waves [7]. However, the longer horseshoe crab is treated, the more horseshoe crab shows dark to light pattern at the time of treatment and straight to light, so it can be indicated that there is a learning behaviour in horseshoe crab [8]. If this happens when a continuous red LED is applied in the field, then the potential for horseshoe crabs to become entangled is still quite high. Therefore, as an alternative used red flicker LED to prevent learning behaviour in horseshoe crab. Other studies related to horseshoe crab response to LED flicker light have not been found, therefore this study aims to compare horseshoe crab response to continuous LED lights and LED flicker and determine the best red LED light to reduce horseshoe crab bycatch on gillnet capture devices.

2. Methods
The research was conducted in April 2019, at the Fish Behavior IPB Laboratory. The number of samples used as many as 20 adult horseshoe crabs measuring 30-38 cm with Tachypleus gigas species obtained from the catch of fishermen in Mayangan [107°31' - 107°54' BT and 60°11' - 60°49' LS]. There are several tools used in the study, including CCTV (Close circuit television) night vision cameras to record the movement of horseshoe crab response, refractometer to measure salinity, treatment body, and LED lights with a continuous intensity effect of $3.68 \times 10^{-6}$ W/cm², and LED flicker light intensity $3.68 \times 10^{-6}$ W/cm². The research method was conducted experimentally laboratory to observe the pattern and and response time of horseshoe crab to continuous red LEDs and red LED flip flop with intensity of $3.68 \times 10^{-6}$ W/cm².

2.1. Horseshoe Crab Maintenance and Preparation
20 Tachypleus gigas are nurtured in fiber tubs measuring 180 cm × 90 cm × 70 cm. The horseshoe crab treatment tub is equipped with an aerator system and the condition is set similar to the actual horseshoe crab habitat state, the salinity up to 28-30 ºº/ [9], the temperature is 24ºC [10], and the atmosphere of the treatment tub is made dim and fed Tubifex sp worms in the late afternoon [11,12]. Preparation of research conducted includes preparation of acclimatization of horseshoe crab for 10 days before treatment, installation of CCTV, led intensity setting and treatment tub. LED lights used are HPL LED with 10 watts power with flicker frequency of 60×/minute [13] and CCTV used with 1080 px specification with 9 fps. CCTV is installed right perpendicular to the top of the treatment tub with a height of 2 meters. The tub used is made of PVC tarpaulin measuring of 280 cm × 195 cm × 50 cm. The zone on the treatment trough is divided into 3 areas, namely start, searching, and finding. At the base of the treatment tub is given a line of marker grids measuring 40 cm × 40 cm for easy observation. Illustration of the treatment tub presented in Figure 1.

![Figure 1](image1.png)

**Figure 1.** Partition of the treatment zone

![Figure 2](image2.png)

**Figure 2.** Sideways view of treatment tub
2.2. Data Collecting
The data collected are the movement patterns of response and speed of horseshoe crab response to continuous LED light and red LED flicker. Data obtained through CCTV footage. Repetition is done 40 times and each repetition is done for 10 minutes. Horseshoe crab movement patterns are grouped into 5 criteria, namely SD [Straight to the dark], LD [Light to the dark], SL [Straight to the dark], DL [Dark to the light], and ST [Stagnant]. The research design used is completely randomized design.

![Graphs showing movement patterns of horseshoe crabs](image)

Figure 3. The illustration of pattern of horseshoe crab responses

2.3. Data Processing
Data of the movement patterns and speed horseshoe crab obtained through CCTV video footage processed using Kinovea software. Kinovea software can produce images in the form of tracking of the movement of horseshoe crabs along with speed time. Furthermore, the results of Kinovea software are presented in the form of images and speed tables.

2.4. Data Analysis
Response patterns that have been grouped into 5 criteria, analyzed descriptively, while response times are analyzed statically and descriptively. To compare horseshoe crab response time to continuous red LED lights and red flip flop LEDs with intensity of $3.68 \times 10^{-6}$ W/cm$^2$, the independent t test was used. But before the independent t test, the data normality test was conducted first by using Kolmogorov smirnov through an application that supports to conduct statistics tests at a level of $\alpha$ 95% [0.05].
3. Result and Discussion

3.1. Avoid Response of Horseshoe Crab Toward Red-Light LED Continuous and Red-Light LED Flicker

The total number of horseshoe crabs staying away from LED light of different types is presented in the percentage graph in Figure 4. The percentage of horseshoe crabs that stay away from the highest light is found in the red LED flicker which is 75%, while 60% on continuous red LEDs. Although the difference between the two is very small, in flicker LED there is no horseshoe crab response that is close to light as in continuous light LED. According to [8] on continuous LEDs with an intensity of $3.68 \times 10^{-6}$ watts/cm², there are still horseshoe crabs that approach the light in an aggressive way, such as attacking the light.

The large number of horseshoe crabs avoiding the red LED flicker compared to the continuous red LEDs indicates that horseshoe crabs do not like the blinking effect produced by the red LED flicker. According to [14] blinking light is able to make marine arthropods to dodge. In addition, it is known that horseshoe crab eyes also do not support to adapt to LED flicker light because it belongs to the type of apposition compound eyes [15]. Arthropods with eye apposition compound eyes tend to avoid light with a blinking effect, as well as main targets such as blue swimming crab which has a different type of compound eye than horseshoe crab which is more tolerant of flicker light LED [16]. Thus, it can be concluded that the red light LED with flicker effect is more effective than continuous red LED in an effort to avoid horseshoe crabs from light.

3.2. Pattern of response of horseshoe crab to the red-light LED continuous and Red-light LED Flicker

Horseshoe crab response pattern to LED light is divided into 5 criteria, namely straight to dark, dark to light, straight to light, light to dark and stagnant. The images show the response pattern criteria shown by the horseshoe crab when given continuous red LED treatment and red flicker LED. Horseshoe crabs that tend to avoid the light showing straight to dark (SD) and light to dark (LD) patterns while when approaching horseshoe crab will show a straight to light (SL) or dark to light (DL) pattern while when horseshoe crab does not respond or dwell in the start area it is called stagnant (ST) [5].

![Avoid Response of Horseshoe Crab to Red Light Continuous LED and Red Light Flicker LED](image)

**Figure 4.** Proportion of horseshoe crab responses
Figure 5. The criteria of horseshoe crab response

In Figures 5, shows that of the two types of LEDs, the highest SD pattern is obtained compared to other patterns. In addition to showing a pattern of staying away, horseshoe crab also shows a pattern of stagnant or fixed in the start area. Stagnant patterns occur because the dark start area conditions resemble the finding dark zone. According to [17], horseshoe crabs have the ability to distinguish contrast between light and dark regions well because they have lateral inhibition abilities.

Figure 6. Avoidance pattern of horseshoe crab

3.3. Time Comparison of Response of Horseshoe Crab to The Red-Light LED Continuous and Red-Light LED Flicker

Response time is the length of time it takes a horseshoe crab to receive stimulus. Response time is the speed obtained from the average in each treatment. A short response time indicates that the horseshoe crab receives stimulus and reacts well and when the response time is longer indicates that the horseshoe crab is slow to receive stimulus [18].

The response time of horseshoe crab is presented in Figure 7. The fastest average response time is on leds with a flicker type of 22.97 seconds, while on continuous LEDs it tends to be slower, which is
32.06 seconds. Based on the independent statistic test t test there is an influence of led type continuous and flicker on response time, this can be seen from the p-value< error level [0.002<0.05). So, it can be concluded that the type of red LED that is best used for mitigation bycatch horseshoe crab is red LED with flicker effect.

![Time of Response of Horseshoe Crab to the red-light LED continuous and Red-light LED Flicker](image)

**Figure 7.** Time of response of horseshoe crab

The dominant proportion of SD response in red light LED flicker intensity of $3.68 \times 10^{-6}$ W/cm$^2$ and the short time horseshoe crab responds in dark conditions with a time of 22.97 seconds can be recommended as the most appropriate intensity of red LED light as an alternative to bycatch horseshoe crab mitigation technology.

4. Conclusion

Based on the results of the study, the largest proportion of horseshoe crabs avoiding light found in led flicker type as much as 75% with SD pattern. The fastest time horseshoe crab avoids LED light is found in flicker red LEDs, which is 22.97 seconds compared to the red LED continuous 32.05 seconds. The most appropriate type of red LED to be used as an alternative technology for bycatch mitigation is a red LED flicker with an intensity of $3.68 \times 10^{-6}$ W/cm$^2$.

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