International Journal of Marine Engineering Innovation and Research, Vol. 10(2), June. 2025. 568-573
(pISSN: 2541-5972, eISSN: 2548-1479)

Light-Emitting Diode for Mitigating Horseshoe Crab (Limulidae) Bycatch of Bottom gill net Fishery for Blue Swimming Crab in the Waters of Ambulu Village, Cirebon Regency

Wazir Mawardi [1], Muhammad Faishal Ashshiddiqi [2], Zulkarnain [3], Am Azbas Taurusman [4], Fis Purwangka [5]
(Received: 17 March 2025 / Revised: 5 June 2025 /Accepted: 23 June 2025 / Available Online: 30 June 2025)

Abstract— **Mimi, a term for horseshoe crabs (Limulidae), often constitutes an unintended bycatch in blue swimming crab (BSC) fisheries employing bottom gill net fishing gear. Three horseshoe species found in Indonesia have been designated as ETP species. This research aims to test the efficacy of red LED Cree lights in BSC bottom gill net fisheries to reduce horseshoe crabs bycatch. The experimental fishing approach was used in Ambulu Village, Cirebon Regency waters, with 17 trips as replication. Two sets of gill nets, one for control and the other for treatment (both equipped with LED lights), were utilized in the study. Data collected were the number of species and individuals of targeted species (BSC) and horseshoe crab as bycatch resulting from the BSC gill net operations in both control and treatment nets. Catch composition used a descriptive analysis. Statistical analyses, including paired sample t-tests and Wilcoxon tests, were conducted on the horseshoe crab bycatch and BSC catch data to test differences between the control and treatment nets. The most abundant catch consisted of crab (Actaeodes tomentosus), with 82 individuals captured in the treatment nets and 87 in the control nets. Blue swimming crab (Portunus pelagicus) caught 76 and 53 individuals in the treatment and control nets, respectively. The bycatch of horseshoe crabs (Limulidae) in the treatment and control nets of 10 and 27 individuals, respectively. The analysis revealed that the BSC catch in the treatment nets did not significantly differ from that in the control nets. Conversely, the horseshoe bycatch observed a significant difference between the treatment and control nets. Incorporating red LED Cree lights resulted in a 35.79% increase in the BSC catch and a 62.96% reduction in the horseshoe bycatch.**

Keywords— Blue swimming crab, Bottom gill net, LED cree light, Horseshoe crabs (Limulidae).

I. INTRODUCTION

A bottom gill net is a fishing gear usually operated on the bottom of the water. The bottom of the water suitable for bottom gill net operation is a sandy or muddy substrate [1]. The main catch of the bottom gill net includes blue swimming crab (BSC) [2]. One of the areas that operate bottom gill net fishing gear on the north coast of Java Island is on the coast of Ambulu Village, Losari District, Cirebon Regency [3]. The bottom gill net, whose target is BSC, is known as kejer net by Cirebon fishermen [4].

Wazir Mawardi, Department of Fisheries Resource Utilization, Faculty of Fisheries and Marine Science, IPB University, Bogor, 16680, Indonesia. E-mail: wazir@apps.ipb.ac.id
Muhammad Faishal Ashshiddiqi, Department of Fisheries Resource Utilization, Faculty of Fisheries and Marine Science, IPB University, Bogor, 16680, Indonesia. E-mail: mfaishal@apps.ipb.ac.id
Zulkarnain, Department of Fisheries Resource Utilization, Faculty of Fisheries and Marine Science, IPB University, Bogor, 16680 Indonesia. E-mail: zulkarnain@apps.ipb.ac.id
Am Azbas Taurusman, Department of Fisheries Resource Utilization, Faculty of Fisheries and Marine Science, IPB University, Bogor, 16680 Indonesia. E-mail: azbas@apps.ipb.ac.id
Fis Purwangka, Department of Fisheries Resource Utilization, Faculty of Fisheries and Marine Science, IPB University, Bogor, 16680 Indonesia. E-mail: fis@apps.ipb.ac.id

BSC has a habitat that matches the substrate of coastal waters [5]. Sandy mud, muddy sand, and clayey mud substrate types are habitats for BSC [6]. Coastal areas with muddy or sandy substrates are also habitats for mimi/horseshoe crabs [7]. The same habitat between BSC and horseshoe crab is often problematic in BSC capture operations using bottom gill net [8].

The horseshoe crab is a type of macrobenthos animal—four worldwide, three of which are found in Indonesia 9]. The morphology of the horseshoe crab is divided into three parts: the front part, which is shaped like a "horseshoe" or prosoma; the middle part, which is shaped like an inverted triangle with a thorn at the end, or opisthosoma; and the back, which shaped like a long thorn or telson [10].

Several studies have been conducted to mitigate horseshoe crab bycatch [11], [12] and [13] have conducted research aimed at reducing horseshoe crab bycatch. Some laboratory-scale studies used the horseshoe crab behavior approach to light to find solutions. The results of some of these studies resulted in a conjecture that horseshoe crabs tend to avoid red light colors with low intensity [12]. However, the results of some of these studies that utilize BSC behavior (approaching red light) and horseshoe crab behavior (avoiding red light) have never been conducted directly in the field (field research).

Direct trials in fishing operations are needed to determine the effects of light on various aspects of fishing operations, such as the effect of net installation on BSC catch and horseshoe crab bycatch. This study examines the effectiveness of using red LEDs in reducing/mitigating horseshoe crab bycatch and the volume of BSC caught.

II. METHOD

The research was conducted in May – June 2023 in Ambulu Village, Cirebon Regency. The method used was the experimental fishing method. Data were collected in 17 replicates (trips).

Experimental fishing was conducted using two units of nets with a length of 220 m each and assembled into one series. Both nets are used as control and treatment nets. Between the treatment net and the control net, a 4 m separation distance was given. The treatment net was equipped with 13 red Cree LED lights and had a distance of 15,7 m between the lights.

Figure. 1. Red LED light.

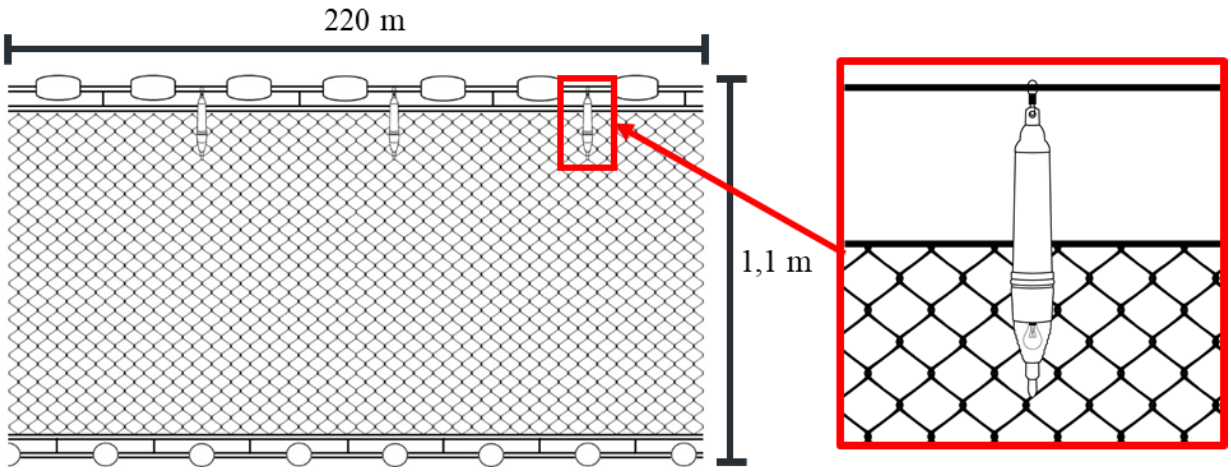

Figure. 2. Placement of red LED lights on the bottom gill net fishing gear.

There are 4 data analysis methods used in this study:

Percentage Composition of Catch

The data analysis used to determine the composition of bottom gill net catches is descriptive. Descriptive analysis is a form of research data analysis to test the generalization of research results based on one sample [14]. [15] also explained that descriptive analysis is used to transform data to make it easier to understand. The catch data was then converted to a percentage with the [16] formula as follows:

$$\text{Specific Species Composition} = \frac{\text{Number of Individual a Species}}{\text{Number of individual of all Species}} \text{x}100\% \quad (1)$$

The processed data is presented in tables and diagrams to make it easier to understand. Data were analyzed descriptively. The aim was to obtain a general description of the species caught in the bottom gill net.

Effectiveness of red LED lights

The horseshoe crab and BSC catch data in the control and treatment net were processed to determine how effective the lights were in mitigating horseshoe crab bycatch and increasing BSC catch. The formula used to assess the effectiveness of increasing BSC catch was as follows:

$$\text{EFFECTIVENESS OF ADDITIONAL CATCH} = \frac{\text{treatment catch} - \text{control catch}}{\text{control catch}} \text{x}100\% \quad (2)$$

The calculation formula for the effectiveness of reducing horseshoe crab bycatch in treatment nets compared to control nets is almost the same as equation (2). The difference lies in the arrangement of variables in the formula. The horseshoe crab bycatch in control nets minus horseshoe crab bycatch in treatment nets divided by horseshoe crab bycatch in control nets multiplied by 100%. The horseshoe crab bycatch in question is the number of individual horseshoe crab in each net, so the equation becomes as follows:

$$\text{EFFECTIVENESS OF BC RDUCTION} = \frac{\text{treatment bycatch} - \text{control bycatch}}{\text{control bycatch}} \text{x}100\% \quad (3)$$

Shapiro Wilk Test

A normality test was conducted to assess whether the data followed a normal distribution, a key assumption for applying many parametric statistical analyses. This study tested the BSC catch weight data and the number of horseshoe crab bycatch in the control net and treatment net to determine the normality of data distribution. The normality test used was the Shapiro-Wilk test. According to [17], the Shapiro-Wilk test is suitable for medium data size (<50). If the data is normally distributed, a paired sample T-test is performed. However, a Wilcoxon test is conducted if the data is not normally distributed.

Paired sample T-test

[18] explain that the paired sample T-test is one of the hypothesis testing methods where the data used are paired. The characteristics encountered are that one individual (research object) was given one treatment and compared with before treatment. In this study, the BSC bottom gill net that does not use lights (control) and the BSC bottom gill net that uses LED lights (treatment).

Wilcoxon Test

The Wilcoxon test evaluates the differences between two or more data samples. In this instance, the test was applied to compare the catch from the BSC bottom gill net treatment with the catch from the BSC bottom gill net control by analyzing the differences in the collected data. The Wilcoxon test in this study examines the catch rates of BSC and horseshoe crab bycatch in both control and treatment nets to determine if there is a significant difference.

III. RESULTS AND DISCUSSION

Composition of catch

Species caught in both nets varied. Some species were only caught in one of the nets. The types of fish that were only caught in the treatment net were seven types *Turitella sp* (15 individuals), *Hyastenus sp* (6 individuals), *Plicofollis dussumieri* (4 individuals), *Strombus sp* (3 individuals), *Lutjanus johnii* (2 individual), *Sphyraena barracuda* (1 individual), *Lutjanus malabaricus* (1 individual). The only two species caught in the control net were *Cynoglossus lingua* (2 individuals) and *Anguilla spp*. (1 individual).

Catch composition is presented in 3 categories: target catches, bycatch, and other catches [19]. The only target catch in the bottom gill net fishery in Ambulu Village was BSC (*Portunus pelagicus*). A total of 129 BSC were caught in the net. The details were 76 individuals (26.3%) in the treatment net and 53 individuals (20.6%) in the control net. The coastal area in Ambulu Village has conditions that are suitable for BSC habitat; therefore, BSC is the main target of bottom gill net catches [4].

The percentage of bycatch in the treatment net was 74 individuals (25.6%), while bycatch in the control net was 78 individuals (30.4%). The bycatch in the treatment net consisted of 9 species, while the control net consisted of 6 species. *Murex sp* (rare-spined murex) was the most common species caught in both nets, with 29 individuals in the treatment net and 40 individuals in the control net. Waters with muddy bottoms are suitable habitats for *Murex sp* [20].

Horseshoe crab is included in the bycatch category. The Horseshoe crab caught in the treatment net was 10, while the control net was 27. Horseshoe crab is included in Nontarget Catches because it does not have a selling price and is not utilized. Horseshoe crabs caught will usually be thrown back into the sea or river. The most common species caught was *Tachypleus gigas*. The treatment net caught five individuals, while the control net caught 12 individuals. The most common species caught in the Mayangan Waters area of Subang Regency in April was *Tachypleus tridentatus* [21], while in August, it was *Tachypleus gigas* [11]. The number of horseshoe crabs caught is related to the migration season of adult horseshoe crabs to tidal areas for spawning.

The percentage of other catches in the treatment net was 139 individuals (48.1%), while other catches in the control net were 126 individuals (49%). Other catches in the treatment net comprised 16 species, while the control net comprised 14 species. Rock crabs were most caught in the treatment and control nets (Cancer sp). There were 82 rock crabs caught in the treatment net, while 87 were in the control net. Rock crabs are usually peeled and utilized as a mixture of BSC meat to increase the weight of BSC meat when sold. The coastal area of Ambulu Village is dotted with floating cages for the cultivation of green mussels, the primary construction material of which is bamboo. Damaged cages will eventually collapse and sink. The submerged bamboos are the living space for rock crabs. That is the reason why rock crabs are the most common catch.

Effect and Effectiveness of Red LED Lights on BSC Catches

The results of 17 replications resulted in a catch of 129 BSC. Seventy-six were caught in the treatment net and 53 in the control net. To determine further testing to be used, the Shapiro-Wilk normality test was conducted on the BSC capture results. All assumptions were tested parametrically at a significance value of 5% (0.05). The normality test results showed that the significance value > 0.05 was 0.386 for the treatment net and 0.712 for the control net. The significance value of both nets showed more than 0.05, which means that the catch data spread normally. Therefore, a paired sample T-test was conducted to determine the effect of lamp use on BSC catch in bottom gill net gear. A paired sample T-test with a 95% confidence interval was conducted, and the result of T of 2.037 was obtained with a T table of 2.120. Based on the guidelines, if T < Ttable means accept H0, it means that the catch of BSC in the bottom gill net treatment is not significantly different from the control bottom gill net. Sig. (2-tailed) value shows 0.059. The α value used is 0.05. The value of sig. (2-tailed) > α (0.05); accept H0, which means there is no significant difference between the weight of the BSC catch of bottom gill net treatment and control bottom gill net.

The paired sample T-test results showed no significant effect between the BSC catch of the control and treatment nets. According to the research of [22] , the pattern of BSC response to light color is divided into two approaches: direct and indirect. Simply put, the pattern of approaching the light color directly is the color of light with the shortest duration approached by BSC. The pattern of indirectly approaching light is the color of light with the most extended duration of being approached by the BSC. Red light is one of the colors that can attract the attention of BSCs and is an indirectly approaching light pattern. Red is the color that has the longest wavelength [23]. Light with a long wavelength is difficult for BSC eyes to respond to. BSCs need more time to adapt to red light. This causes BSC to last longer in an environment exposed to red light. Following [22] found that BSC survived longer in areas illuminated by red and orange light. Red light is not the light that attracts the attention of BSCs the fastest. The light that attracted BSCs to approach faster was blue and included a pattern of approaching the light directly [22]. However, blue light cannot repel horseshoe crabs to move away.

One of the environmental factors that affect light penetration is water turbidity. Water turbidity in Ambulu Village is classified as low, with the dominance of NTU data <0.1. Low turbidity causes light to penetrate better. Light can reach a wider net and water column. This is likely why the BSC catch in the treatment net was higher than in the control net.

The data processing results using the paired sample T-test showed no significant difference between the catch of BSC in the control and treatment nets. However, the results of calculating the effectiveness of using LED lights on the bottom gill net showed more catches. The effectiveness of BSC catch in the treatment net was 35.79% more than the control net. According to [22], red light is one of the colors that attracts the attention of BSC with the longest duration movement pattern.

TABLE 1.
CATCH COMPOSITION

No	Common name	Species name	Treatment		Control	
			Indv.	%	Indv.	%
1	Rock Crab	*Actaeodes tomentosus*	82	28.4	87	33.9
2	Blue Swimming Crab	*Portunus pelagicus*	76	26.3	53	20.6
3	Mantis Shrimp	*Harpiosquilla raphidae*	14	4.8	1	0.4
4	Green Mud Crab	*Scylla paramamosain*	9	3.1	10	3.9
5	Indo-Pacific Horseshoe Crab	*Tachypleus gigas*	5	1.7	12	4.7
6	Squat Lobster	*Hyastenus* sp	6	2.1	0	0.0
7	Chinese Horseshoe Crab	*Tachypleus tridentatus*	3	1.0	10	3.9
8	Mangrove Horseshoe Crab	*Carcinoscorpius rotundicauda*	2	0.7	5	1.9
9	Crucifix Crab	*Charibdis feriatus*	1	0.3	4	1.6
10	Mangrove Crab	*Scylla serrata*	1	0.3	2	0.8
11	Fourfinger Threadfin	*Polynemus tetradactylus*	7	2.4	13	5.1
12	Rough Flathead	*Grammoplites scaber*	6	2.1	3	1.2
13	Milkfish	*Chanos chanos*	5	1.7	2	0.8
14	Cowtail Stingray	*Trygon sephen*	4	1.4	1	0.4
15	Giant Catfish	*Netuma thalassina*	4	1.4	2	0.8
16	Blacktip Sea Catfish	*Plicofollis dussumieri*	4	1.4	0	0.0
17	Butterfish	*Drepane punctata*	2	0.7	6	2.3
18	Bleeker's Grouper	*Epinephelus bleekeri*	2	0.7	1	0.4
19	Japanese Meagre	*Argyrosomus japonicus*	3	1.0	1	0.4
20	Mangrove Snapper	*Lutjanus johnii*	2	0.7	0	0.0
21	Barracuda	*Sphyraena barracuda*	1	0.3	0	0.0
22	Malabar Red Snapper	*Lutjanus malabaricus*	1	0.3	0	0.0
23	Commerson's Sole	*Dagetichthys commersonnii*	0	0.0	2	0.8
24	Indonesian Shortfin Eel	*Anguilla* spp	0	0.0	1	0.4
25	Rare-Spined Murex	*Murex* sp	29	10.0	40	15.6
26	Tower Shell	*Turitella* sp	15	5.2	0	0.0
27	Fighting Conch	*Strombus* sp	3	1.0	0	0.0
28	Blood Cockle	*Anadara granosa*	2	0.7	1	0.4
	Quantity		289	100	257	100

Effect and Effectiveness of Red LED Lights on the Catch of Horseshoe Crab

Based on 17 trips, the treatment bottom gill net caught 10 horseshoe crabs, and the control bottom gill net caught 27 horseshoe crabs. Shapiro-Wilk test was conducted on the horseshoe crab bycatch data of bottom gill net treatment and bottom gill net control. The normality test result for horseshoe crab bycatch data in the control net was 0.184, and the treatment net was 0.000. The significance value is 0.05. The significance value of the control net is 0.184 > α (0.05), and the treatment net is 0.000 < α (0.05). The control net data is usually distributed, while the treatment net data is not normally distributed. The following test data were analyzed comparatively using the Wilcoxon test to determine whether red light really affected the number of horseshoe crab bycatch. The Wilcoxon test was conducted on horseshoe crab bottom gill net treatment and control bottom gill net bycatch data and obtained a Z of 2.750. The Z table for α 0.05 is 1.645. Since Z (2.750) > Z table (1.645), then reject H0, which means there is a significant difference in horseshoe crab bycatch between the treatment net and control net. Significance value < 0.05). This states that using red LED lights really affects the number of horseshoe crab bycatch in bottom gill net gear. Sig. (2-tailed) shows a value of 0.006. The α value used is 0.05. Sig. (2-tailed) 0.006 < α value of 0.05, then reject H0, meaning there is a significant difference between horseshoe crab bycatch in control and treatment nets.

The Wilcoxon test results show a significant difference between horseshoe crab bycatch in the control and treatment nets. Bycatch horseshoe crab in the control net is more than the treatment nets. According to [12], Green, purple, and blue lights impact horseshoe crab behavior patterns to approach the light source, in contrast to red light, which impacts horseshoe crab behavior patterns to move away. In their research, [13] found that horseshoe crabs were quickest to avoid red at low light intensity. Horseshoe crabs have difficulty adapting to low light intensity [24].

Using bottom gill net gear, Red LED lights can be used in BSC fisheries. The nature of red light produces different responses in horseshoe crabs and BSC. Horseshoe crab and BSC have different types of eyes [13]. Horseshoe crabs have apposition compound eyes with a low tolerance level to light compared to BSC eyes, which are superstition compound eyes [25]. The inability of horseshoe crab eyes to adjust to red light causes a response away from red light sources [11]; [12]. The calculation of the effectiveness of LED lights also supports the assumption that horseshoe crabs avoid red light with a reduction in horseshoe crab bycatch caught in the treatment net, 62.96% lower than the control net.

IV. Conclusion

The composition of the catch was divided into three categories; Target catch in the form of Blue Swimming Crab (*Portunus pelagicus*) with 76 individuals (26.3%) in the treatment net and 53 individuals (20.6%) in the control net, bycatch dominated by *Murex sp* with 29 individual (10.0%) in the treatment net and 40 individual (15.6%) in the control net, and other catches dominated by rock crabs (*Cancer sp*) with 82 individual (28.4%) in the treatment net and 87 individual (33.9%) in the control net. There was no significant difference in BSC weight between the catches of the treatment and control nets. However, there was a significant difference between the number of horseshoe crab individuals in the catches of the treatment and control nets. Red LED light increased BSC catch 35.79% higher than the control net and mitigated/reduced 62.96% of horseshoe crab catch compared to the control net.

References

[1] Ernawati T, Budiarti TW, Yuniarta S. 2021. Fisheries management for the blue swimmer crab (Portunus pelagicus) in the Java Sea, Indonesia. In: Loneragan N, Wiryawan B, Hordyk A, Halim A, Proctor C, Satria F, Yulianto I, editors. Towards sustainability - applying the method evaluation and risk assessment tool to seven Indonesian fisheries. p. 29–49.

[2] Lubis F, Muliyana A, Rahmi MM, Rizki HM. 2021. Analisis rajungan (Portunus pelagicus), komposisi bycatch dan alat tangkap jaring dari tangkapan nelayan di perairan Kabupaten Asahan Sumatera Utara. J Aceh Aquat Sci. 5(2):80–87.

[3] Badan Pusat Statistik. 2021. Cirebon Regency in Figures 2021. Cirebon: BPS Cirebon Regency.

[4] Al Bayyinah A, Nurkhasanah D. 2020. Status alat tangkap jaring kejer di Cirebon, Jawa Barat. Mar Fish J Mar Fish Technol Manag. 11(2):135–146.

[5] Wahyuningsih S, Fatimatuzzahroh F. 2019. Kondisi mangrove di pesisir Kabupaten Cirebon. Syntax Literate. 4(7):116–130.

[6] Ernawati T, Boer M, Yonvitner Y. 2015. Biologi populasi rajungan (Portunus pelagicus) di perairan sekitar wilayah Pati, Jawa Tengah. Bawal Widya Capt Fish Res. 6(1):31–40.

[7] Ubaidillah R, Marwoto RM, Hadiyaty RK, Fahmi DW, Mumpuni RP, Tjakrawidjaja AH, Mujiono N. 2013. Biota perairan terancam punah di Indonesia prioritas perlindungan. Jakarta: KKP.

[8] Supadminingsih FN, Wahju RI, Riyanto M. 2019. Composition of blue swimming crab Portunus pelagicus and horseshoe crab Limulidae on the gill net fishery in Mayangan waters, Subang, West Java. Bioflux. 1(12):14.

[9] Mashar A, Butet NA, Juliandi B, Qonita Y, Hakim AA, Wardiatno Y. 2017. Biodiversity and distribution of horseshoe crabs in the northern coast of Java and southern coast of Madura. IOP Conf Ser. 54(1).

[10] Pratiwi R. 1993. Mimi (horse shoe crab) penyebar maut yang dilindungi. Oceana. 18(1):25–34.

[11] Supadminingsih FN. 2018. Tingkah laku mimi (Limulidae, 1819 Leach) terhadap lampu LED warna hijau [skripsi]. Bogor: Bogor Agricultural University.

[12] Utami A. 2018. Tingkah laku horseshoe crab terhadap warna cahaya berbeda [skripsi]. Bogor: IPB.

[13] Rahayu R, Wahju RI, Mawardi W. 2019. Respons mimi terhadap cahaya lampu LED merah dengan intensitas yang berbeda untuk mitigasi bycatch jaring insang dasar. Saintek Perikanan. 15(2):119–123.

[14] Hasan I. 2004. Analisa data penelitian dengan statistik. Jakarta: PT Bumi Aksara.

[15] Istijanto. 2009. Aplikasi praktis riset pemasaran. Jakarta: Gramedia Pustaka Utama.

[16] Krebs CJ. 1985. The experimental analysis of distribution and abundance. New York: Harper and Row.

[17] Ruxton GD, Wilkinson DM, Neuhäuser M. 2015. Advice on testing the null hypothesis that a sample is drawn from a normal distribution. Anim Behav. 107:249–252.

[18] Montolalu C, Langi Y. 2018. Pengaruh pelatihan dasar komputer dan teknologi informasi bagi guru-guru dengan uji-t berpasangan. d'CARTESIAN J Math Appl. 7(1):44–46.

[19] Wang JH, Fisler S, Swimmer Y. 2010. Developing visual deterrents to reduce sea turtle bycatch in gill net fisheries. Mar Ecol Prog Ser. 408:241–250.

[20] Lee G, Stokes J. 2006. Marine science: an illustrated guide to science. New York: Chelsea House Publishers.

[21] Putra DA. 2019. Hasil tangkap sampingan mimi (Limulidae) pada jaring insang rajungan di perairan Mayangan, Kabupaten Subang [skripsi]. Bogor: Institut Pertanian Bogor.

[22] Hasly IRJ, Yusfiandayani R, Mawardi W. 2019. Respons rajungan (Portunus pelagicus) terhadap warna cahaya yang berbeda pada uji laboratorium. J Penelit Perikanan Indones. 25(4):215–224.

[23] Alfira A, Ajar S, Hanim N. 2021. Pengaruh warna lampu terhadap kehadiran serangga nocturnal di kawasan kampus UIN Ar-Raniry Banda Aceh. Proc Natl Biotic Semin. 9(2):12–15.

[24] Barlow RB. 2015. Vision in horseshoe crabs. In: Tanacredi JT, et al., editors. Biology and conservation of horseshoe crab. p. 223–247.

[25] Rochow VBM. 2001. The crustacean eye: dark/light adaptation, polarization, sensitivity,