Stolephorus sp Behavior in Different LED (Light Emitting Diode) Color and Light Intensities

Fitri Aristi D P1*, Ramadanita I A1, Hapsari T D1, Susanto A2

1Faculty of Fisheries and Marine Science, Diponegoro University, Semarang, Indonesia
Email: aristidian@fisika.undip.ac.id
2Faculty of Agriculture, Sultan Ageng Tirtayasa University, Banten, Indonesia

Abstract. This research aims to observe anchovy (Stolephorus sp) behavior under different LED light intensities that afect eye physiology (cell cone structure). The materials used were Stolephorus sp taken from the waters off Jepara and 13 and 10 watt light emitting diode (LED). The research method was an experiment conducted from March through August 2015 in the waters off Jepara. Data analysis of visual histology and fish respond was carried out at the fishing gear material laboratory, anatomy and cultivate. Cone cell structure (mosaic cone) of Stolephorus sp forms a connected regular square pattern with every single cone surrounded by four double cones, which indicate that anchovies are sensitive to light. The 13 watt LED (628 lux) has faster response than the 10 watt LED (531 lux) as it has wider and higher emitting intensity, which also attracts fish to gather quicker.

Keywords:

1. Introduction

Anchovies (Stolephorus sp) are one of the economically important fish in Indonesia. There are 9 types of Anchovy spread throughout the Indonesian waters. Anchovies have positive phototaxis characteristic. This means going toward a source of light. This trait is used ineffectively capturing them. Wiyono (2006)[1] Notanubun and Patty (2010)[2] Fitri et al (2017)[3] Fitri et al (2017)[4] stated that utilization of light in fishing operation has well developed since the invention of electric light to capture phototaxis positive fish. Most fishermen believe that greater light intensity increases their catch. Therefore, they operate using all kinds of high intensity lights. However, this assumption is not entirely correct as different fish has different light intensity preferences such as the case for in puffer fish that can be caught using either kerosene or mercury pressure lantern Rasyidah (2009)[5].

According to Sulaiman et al (2015)[6], LED flood light is the best lighting to replace lamp which has a high cost of maintenance and operation. LED lights run deeper through water and attract fish located far away from the light source. LEDs are also more efficient than the other types of lights. Moreover, they are commercially available in the market. Hence, this research used the 13 watt and 10 watt LED lights.
Behavioral research on the retina of pelagic fish has not been widely conducted. Data on this are very important to know the proper exposure to light during fishing operation. This correlates to the time when fishermen should lift the net as they see schools of fish under the light. This leads to effectiveness in capturing process as prolonged exposure to light may cause burnout on the fish.

The above mentioned facts lead to this research on light intensity to attract anchovies at the laboratory scale. It is aimed at figuring out the proper light duration by analyzing cell cone structure and behavior of anchovies under different LED light intensities. According to Notanubun and Patty (2010)[2], there needs to be a study on the light intensity that can attract fish of all species, as this will lead to more efficient fishing budget.

2. Method
Living anchovies (*Stolephorus* sp) were collected from Jepara waters. Thirteen and 10 watt LEDs were paired at a reflector to focus the lights. The treatment tanks were 4 units made of cement with L x W x T : 319 x 168 x 115 cm, and each tank is given number 1 for nursery, number 2 and 3 for treatment tanks and number 4 for post- treatment tank. Every treatment tank was also given a mark for the 1st zone with light intensity of 737-2217 lux, the 2nd zone with 487-779 lux intensity and the 3rd zone with 216-292 lux intensity. Tank depth was also given three scales of layers; 1-26 cm, 27-52.7 cm and 53.7-77.5 cm, and the water in the tank and the LED lights were separated 34 cm apart.

Measurement of light intensity was carried out using an underwater lux meter with data logger. An illustration of the experiment tank with observation zones in both vertical and horizontal directions is shown in Figure 1.

![Figure 1. Design of treatment tank with different observation zones.](image-url)

This study was conducted in 2 stages. The first stage was data collection by observation. Data were taken using digital cameras that observe and record directly. Primary data counted the total fish entering in 1st, 2nd, and 3rd zone per 5 minutes for 1 hour. The treatment started from the moment the lights were switched on and the depths of fish position were used as data. Each treatment tank consisted of approximately 100 anchovies. Prior to the treatment, the fish were adapted for 1 week with 1 feeding/day and the feed was natural feed (*zooplankton*). Treatments were carried out at night in dark condition and only
the LEDs were on. Treatments were done in 6 repetitions for each lighting power. The second treatment was dissection of anchovies’ eyes with histological process and each sample was instantly killed to keep the eye receptor unaffected.

Data were arrangements of cone cell structures which describe the structure of cone cell (mosaic cone) as visual cells in the retina. These observations were conducted to know the form of mosaic cones which are arranged in square patterns. Fish that have cone cell in square structures use their visual sense intensively. In most fish species, a double cone is similar to a twin cone and a single cone only consists of one cone cell (Loew and Lyhtgoe, 1978)[7].

3. Results and Discussion
3.1. Light Intensity
Results of light intensities from the 13 watt and 10 watt LEDs are shown in Figure 2.

Figure 2. Light intensities of the 13 watt and 10 watt LEDs.

Figure 1 shows that the 13 watt LED has the highest light intensity in zone 3 at 1-26 cm depth with 2217 lux and the lowest light intensity in zone 1 at 52.7-77.5 cm depth with 275 lux. Meanwhile, the 10 watt LED has the highest light intensity in zone 2 at 1-26 cm depth with 1633 lux and the lowest intensity in zone 1 at 1-26 cm depth with 216 lux.

These results are used as a reference to know the ideal light intensity at which Anchovy can adapt perfectly. Light intensity for the 13 watt LED in each zone and depth is higher than for the 10 watt LED. Light intensity tends to decrease with increasing depth, and it tends to increase with closer light source. Yami (1987)[8] explains that the light intensity (lux) of light source will decrease with increasing distance and will decrease when the light goes into the water due to refraction.

3.2. Fish response time against different light intensities
Time response against light intensities for the 13 watt and 10 watt LEDs are shown in Figure 3.

Figure 3. Time Fish response against the light.
Result in Figure 3 show that the fastest time for the 13 watt LED is 3.9 minutes, compared to 7.27 minutes for the 10 watt LED. These are the times the fish move from dark toward the lights. The 13 watt LED has faster response than its 10 watt counterpart as the average fish response time is 3.13 minutes, whereas for the 10 watt LED, it is 28 minutes. This is due to the fact that the 13 watt LED has wider and higher emitting intensity. According to Sulaiman et al (2015)[6], Fish start to enter the light area under lift net frame after 5-10 minutes. Therefore, the first type of fish entering is small fish, followed by anchovies and the others. Ayodhya and Diniah (1989)[9] argued that the number of fish gathered under the light depends on the power of the light. The greater the power of the light, the more fish it attracts.

3.3. The number of fish responding to different light intensities

Table 1. The number of respond fish to the 13 watt LED light intensity.

| Minute | 829-2217 Lux | 527-779 Lux | 275-292 Lux |
|--------|--------------|-------------|-------------|
| 5      | 0            | 1           | 0           |
| 10     | 0            | 1           | 0           |
| 15     | 0            | 2           | 0           |
| 20     | 3            | 3           | 0           |
| 25     | 2            | 4           | 0           |
| 30     | 0            | 1           | 0           |
| 35     | 1            | 1           | 0           |
| 40     | 2            | 1           | 0           |
| 45     | 2            | 1           | 0           |
| 50     | 3            | 1           | 0           |
| 55     | 0            | 2           | 0           |
| 60     | 0            | 0           | 0           |

Average: 2.67, 22.40, 11.42
Standard Deviation: 1.15, 13.72, 8.65

Figure 4. The number of respond fish to the 13 watt LED light intensity.
Table 2. The number of respond fish to the 10 watt LED light intensity.

| Minute | 737-1633 Lux | 487-613 Lux | 216-247 Lux |
|--------|--------------|-------------|-------------|
| 5      |              |             |             |
| 10     |              |             |             |
| 15     | 2            | 3           | 5           |
| 20     |              | 13          | 10          |
| 25     |              | 15          | 5           |
| 30     |              | 8           | 4           |
| 35     |              | 13          | 8           |
| 40     | 2            | 14          | 2           |
| 45     |              | 15          | 9           |
| 50     | 1            | 12          | 13          |
| 55     | 2            | 21          | 19          |
| 60     | 12           | 17          |             |

Average 1.67 12.60 8.55

Standard Deviation 0.58 4.70 5.79

Figure 5. The number of respond fish to the 10 watt LED light intensity.

Results in Figure 4 show that the number of fish in each zone observed every 5 minutes in 1 hour. First, in the 4th minute there are 4 fish gathering in the zone of 275-292 lux intensity. At 15 minutes, there are also 4 fish gathering in the zone of 527-779 lux intensity. The highest number of fish is in the 40th minute in the zone of 829-2217 lux intensity. There are 14 individuals. In the zone of 527-779 lux intensity there are with 48 individuals, and in the zone of 275-292 lux intensity there are 17 individuals. This indicates that the fish began to respond interested in the intensity of the 13 watt lights at 40 minutes after the lights are turned on, and located in zone 2. Zone 2 is the area that has the most preferred lamp intensity of the fish, while zone 1 because the area is right under the light source do not react fast to fish.

It is also observable in Figure 5 that in the 10th minute, the fish start move to the 216-779 lux intensity zone from dark zone, with 2 individual going first. In the 15th minute, the fish move to the 487-613 lux
intensity zone, with 13 individuals. The lowest number of fish is in the 55th minute in the 737-1633 lux zone, with only 2 individuals and the highest is in the 487-613 lux zone, with 21 individuals, and the number is even smaller after the 55th minute. Average adaptation time of fish with 10 watt lamp intensity is different with 13 watt lamp intensity, which takes longer adaptation time compared to 13 watt lamp. Zone 2 remains the most dominant area of adaptation compared to zone 1 and zone 3. This is because zone 1 which is right below the light source and zone 3 which is 144 cm area is a zone that does not attract fish to approach and do long adaptation.

3.4. The number of fish both 13 watt and 10 watt LEDs

The highest number of fish in the 13 watt treatment is in the 40th minute at 628 lux intensity with 48 individuals. Light intensity of 529 lux has 27 individuals, while the lowest number of fish is in the 779 lux intensity. Meanwhile, the 10 watt treatment has the highest number of fish in the 55th minutes at 531 lux intensity with 21 fish, whereas at 487 lux intensity there are 19 fish and at 613 lux intensity there are only 2 individuals of anchovy. From Figure 6 and Figure 7, it can be concluded that the light intensity of 628 lux at 13 watt lamp and 531 lux light intensity on 10 watt lamp attract fish more than other intensity because it can make fish to adapt longer on that intensity. In addition, the 13-watt lamp is able to attract more fish to gather than a 10-watt lamp.
3.5. Anchovy behavior

This laboratory scale research observes the anchovy’s behavior against LED light intensity from 13 watt and 10 watt bulbs. These LED bulbs are available in the market a 10 watt LED has similar light intensity with a 24 watt TL (neon light), while a 13 watt LED equals the light intensity of a 42 watt TL light. Prior to the treatment, the fish were adapted to dark condition. The dark area serves as the starting point before lights were turned on, right after which the fish start to move toward them.

Observations were made every 5 minutes after the light source was turned on, and was done for 1 hour. Every treatment has 6 repetitions. Anchovies tend to swim in the bottom layer irregularly. According to Hermawan (2005)[10], the behavioral response of “Red snapper” to different colors and powers of lights can be known if they are treated in dark condition long enough before a treatment is administered.

Observations of the behavior of anchovy under both 13 watt and 10 watt illuminations show that longer lighting period leads to more fish gathering in the area. For the 13 watt LED, the number of fish increases until the 40th minute with 48 individuals in the light intensity of 628 lux. In the light intensity of 529 lux there are with 27 fish, and in the 779 lux intensity, there are 2 fish. After 40 minutes, the number of fish decreases until 60 minutes. This is because longer exposure period increases water temperature that the area is no longer comfortable for fish to gather at. For the 10 watt LED, the highest number of fish is in the 55th minute with 19 individuals at 487 lux light intensity. At 531 lux intensity there are 21 fish, and at 613 lux intensity there are 2 fish.

Anchovy’s movements in both 13 watt and 10 watt LED illumination are twisting and surrounding the light area. According to Sudirman et al (2004)[12], anchovy tends to choose higher exposure, swim at the surface of water, and quickly enter area so that need no long period of adaptation to light is required. Instead, the longer period of exposure saturates Anchovy and this keeps them away from the light source.

Based on visual observations, Anchovy prefers the area of 27-52.7 cm depth with light intensity between 281-628 lux. This is consistent with an earlier research by Sulaiman et al (2015)[6], which explained that anchovy swims in areas of 1-15 m depth with 16-650 lux illumination intensity. According to Godo et al (2004)[13], anchovy swims in the area of 1-15 m because this area has positive photo taxis characteristic. This study argues that a 13 watt LED attracts Anchovies faster than its 10 watt counterpart. Therefore, it can be applied in the field to capture fish with an optimum light intensity of 281-628 lux, and an exposure time of 40 minutes.

Anchovy can adapt optimally in the adaptation process but this should be observed further in a laboratory scale. Sudirman (2003)[11] explains that from the aspect of light adaptation process, anchovies’ retina tend to like high intensity lighting. This is based on observations of their cone cells, which shows that their pigments quickly adapt to light intensity. Normally, the number of hauling processes in a trip is 3 times. For the case of high number of anchovy present, then the number of hauling process can be add by 4 – 5 times a night. In other words, attracting this type of fish only requires 2 hours of light immersion into the water.

The 13 watt and 10 watt LEDs do not have differences in attracting fish. The only factor affecting attraction to fish is illumination as more fish are observed to be attracted to the lighting zone of 281-628 lux intensity. The number of fish attracted seems to be influenced by the range of lighting by the diameter of the LEDs. The light used in this study has different diameters for each lighting zone. The 13 watt LED has 116 cm diameter and is wider than the 10 watt LED, which is put at 27-51.7 cm depth with 108 cm of diameter. The range of lightings influenced the number of fish gathering under the light. According to Ayodhya and Diniah (1989)[9], the number of fish which gather under the light depends on lighting power. The stronger the light, the faster fish approach the light source.

3.6. Cone cell structure

Figure 8 shows the cone cell structure of anchovy’s retina (Stolephorus sp). It can be seen that the composition of eye cell model is of single or double cone and is mosaic in shape. Fish with mosaic cone cell response faster to light. According to Razak et al (2005)[14], fish that have mosaic cone cell in line or square shape are very intensive in the use of their visual sense. Other than that, a mosaic eye cell structure (single or double cone cell) indicates that the fish is sensitive to light, both against its intensity and spectrum. Therefore, fishing operation using lift net at night should consider the effect of lighting, because light is key for the success of catching photo taxis fish such as anchovy.
Figure 8. Structure of the cone cell.

4. Conclusion
There are difference is the behaviors of Stolephurus sp against different light intensities from LEDs. A 13 watt LED gets faster response from this type of fish (3.9 minutes), whereas a 10 watt LED gets a slower response (7.27 minutes). More fish gather under the illumination of a 13 watt LED with 628 lux intensity, compared to those gathering under the illumination of a 10 watt LED with 531 lux intensity. These differences in behaviors are also affected by the eye cell structure of Stolephurus sp with its characteristic mosaic pattern, which indicates that this type of fish is sensitive to different light intensities.

Acknowledgement
The authors wish to thank The Laboratory of Coastal Area Development (LPWP) Jepara, The Laboratory of Aquaculture of The Faculty of Fisheries and Marine Science, Diponegoro University Semarang, and Aziz Afriandi for his assistance.

References
[1] Wiyono E 2006. J. of Tropical Fisheries Science 18 2
[2] Notanubun, J and Patty 2010 Thesis Sam Ratulangi University Manado
[3] Fitri A D P, Boesono H, Sabdono A, Nadiaadlina N 2017 55 1 012008
[4] Fitri A D P, Boesono H, Sabdono A, Supadminingsih F N, Nadiaadlina N 2017 AAACL Bioflux 10 2 pp 191199
[5] Rosyidah 2009 Indonesian Journal Marine Science 2 1 1907
[6] Sulaiman M, Mulyono S B, Am A T Sugeng H W, and Roza Y 2015 J of Tropical Marine Science and Technology 7 1
[7] Loew and Lythgoe 1978 The ecology of vision Clarendon Press Oxford
[8] Yami B M 1987 Fishing With Light. Agriculture Organization of The United Nation by Fishing News Books Ltd Farnham Surrey England pp 121
[9] Ayodhya and Diniiah R 1989 Animal Food (Post-Mortem Physiology and Technology) Graha Ilmu Yogyakarta pp 103
[10] Hermawan R 2005 Thesis Faculty of Fisheries and Marine Science Diponegoro University
[11] Sudirman 2003 J. of Aquatic Sciences and Fisheries Indonesia 3 28
[12] Sudirman, M S Baskoro, A Purbayanto, D R Monintja, M Jufri and T Arimoto 2004 J. of Aquatic Sciences and Fisheries Indonesia 10 2 85
[13] Godo O R V, Hjellvik S A, Iversen A S, Lotte E Tenningen and T Torkelsen 2004 J. ICESJMS 61 7 1093
[14] Razak, A K Anwar and M S Baskoro 2005 Physiology Fish Eye Faculty of Fisheries and Marine Science Bogor Agriculture Institute Publisher. Bogor pp 111