The optimum light colour and intensity of light emitting diodes for catching yellowstripe scads (Selaroides leptolepis) using fixed liftnet

M Riyanto1, A Susanto2, M S Baskoro1, S H Wisudo1 and F Purwangka1

1Department of Fisheries Resource Utilization, Faculty of Fisheries and Marine Science, Bogor Agricultural University, Bogor, Indonesia
2Department of Fisheries, Faculty of Agriculture, University of Sultan Ageng Tirtayasa, Banten, Indonesia

*E-mail: mochammadri@apps.ipb.ac.id

Abstract. The effectiveness of green light emitting diodes (LED) in influencing the behaviour of fish has not been investigated. This study aimed to determine the optimum color and light intensity for catching yellowstripe scads (Selaroides leptolepis) based on their behavioral response and light adaptation. An experiment used two types of LED, blue and green, operated at three levels of light intensity, low (20 lx), medium (35 lx) and high (50 lx). The experiment was conducted in a tank to determine the fish preference zone and pattern of behavioral response to different colors and light intensities. Their retinal adaptations were investigated histologically. For all colours and light intensities, the schooling fish was located mainly in the bright zone (67%). The cone index and swimming speed of fish were slightly increased by intensity. The highest light adaptation was found on blue LED exposure at a light intensity of 88.70%. When being exposed to the green LED, the fish gradually swam closely to each other and formed a stable schooling formation. However, when being exposed to the blue LED, the fish keep swimming widely and randomly. The green LED was an excellent fishing lamp for controlling behavior and harvesting yellowstripe scad in liftnet fishing.

Keywords: behavioural, colour, intensity, LED, response

1. Introduction

The small-scale light fishing activities in Indonesia mainly use compact fluorescent lamps (CFLs) to attract fish with a different number and light power (watt). The fishers prefer the CFL because it is easy to obtain, low cost [1-2] and considered bright enough to attract schooling fish [3]. The shortage, however, CFLs require high power, short lifetime and high heat radiation [4-5]. Moreover, the light from the CFLs does not necessarily reach the fish target or catchable area, thus a better alternative fishing lamp is needed to ensure the effectiveness of the light fishing.

White light emitting diode (LED) appears to be one of the alternatives of the lamp for fixed lift-net (bagan tancap) fishing in Banten Bay. Its use was reported successful in increasing main catches up to 29% and saving energy up to 35% [6]. When operated underwater in Banten Bay, blue LED can
increase the catch of yellowstripe scad (Carangidae) by 10-20%. However, the use of LED lamp in light fishing is still experimental and the results are still limited. The effectiveness of the LEDs to different species measured in their behaviour needs to be investigated.

Members of Carangidae have a maximum spectral sensitivity ($\lambda_{\text{max}}$) at 494-500 nm (green light) in varies intensities [7]. The minimum intensity for maintaining fish schools ranged from $9.4 \times 10^{-13}$ W/cm² to $1.2 \times 10^{-6}$ W/cm² [8-10]. Appropriate color and intensity of fishing lamp would increase the effectiveness and efficiency of fixed lift-net fishing. The purpose of this study was to determine the behavioural response of yellowstripe scad to blue and green LED light at the different intensity as a basic evident to select appropriate fishing lamps for fixed lift-net fisheries.

2. Methods

2.1. Fish

Yellowstripe scads (total length (TL) = 6.0-12.0 cm, N=60) were collected by a guiding barrier (sero) at Banten Bay and transferred to the laboratory for adaptation and acclimatization period. The water salinity in adaptation tank was 30-33 ‰, the temperature ranged 29-31°C, and dissolved oxygen ranged from 5.9-6.1 mg/L. Both before and after the experiments, fish were fed two times every day with Arthemia sp. All experiments were conducted from October 2017 to February 2018 in Serang City Banten Province.

2.2. Experimental Condition

All experiments were carried out on black fiberglass tank with 10 cm dot marked at the bottom of the tank as calibration scale. The tank was divided into six zones as shown in figure 1. Before being tested, 30 fish (total length ranged 6.0-12.0 cm) were placed into the experimental tank for three days to acclimate. Lamps were built using 4 dual inline packages (DIP) LEDs mounted on the metal housing (L x W x H 11.0 cm x 5.0 cm x 7.0 cm), powered by 4 V DC supply. The experiment was conducted in two colours of LED (blue and green) and three illuminations (20 lux, 35 lux, 50 lux). Light intensity was measured with ILT 5000 research radiometer. The number of green LED intensity were 20 lx = 24 μW/cm², 35 lx = 54 μW/cm², 50 lx = 90 μW/cm². Meanwhile the blue LED has high intensity, was 20 lx = 478 μW/cm², 35 lx = 606 μW/cm² and 50 lx = 788 μW/cm².

![Figure 1. Tank experiment for behavioural response.](image-url)
of the fish. Video recording using the infrared camera was conducted during the experiment (dark and light condition). A total of 540 minutes of video recording was analysed for each colour.

After the behavioural response experiment, two individuals of the fish were transferred to the circular tank for the cone adaptation experiment. The circular tank was kept in dark condition for 30 minutes, continue with light exposure for 30 minutes in each experiment, then the fish was immediately killed to remove the eye for the histological process. Eyes were oriented using the location of the ventral choroid fissure and trimmed in a dorsal-ventral plane to include the optic nerve. Subsequent processing to paraffin wax was routine and sections were stained with Hematoxylin and Eosin [9,12].

2.3. Data analysis
The following parameters were considered: (1) proportion of fish at each zone, to determine the degree of attraction/preference on light stimuli (2) cone index, to determine the level of retinal adaptation to light exposure and (3) swimming pattern, to determine swimming and behavioural response on light stimuli. The proportion of fish in each zone was analyzed by calculating the number of fish gathered in each zone at each observation minute [13]. Cone index calculated from the center of the cone position and the thickness of the visual layer [14]. Fish behaviour was analyzed using video tracking of dominant swimming patterns that occur in each treatment [11].

3. Results and Discussions

The yellowstripe scads preferred light zone than the dark zone. It proportions on a light zone of blue and green LED ranged 33-43 percent and 28-40 percent respectively. Meanwhile, the fish proportion on dark zone ranged 5-15 percent and 5-14 percent for blue and green LED respectively. Moreover, the fish proportion in dark condition has a similar number at all observation zones, ranged 14-19 percent (figure 2). The applications of higher intensity at the same color of LED have a significant influence on fish proportion on the bright zone (p<0.05). The number of fish around light source was higher at a higher level of light intensity [11].

The cone index at a dark condition was only 31.5%. Green LED produced higher cone index than the blue LED at the low and middle intensity. Meanwhile, the blue LED formed the greatest cone index at the high intensity. Its index using blue LED ranged between 86.0-88.7% and green LED had cone index between 86.3-87.8% as shown in figure 3. The level of retinal adaptation is directly proportional to the increase of light intensity in each color. In the same color, cone cells adapt more quickly to higher light intensities compared to lower light intensities. Cone cells of the fish retina become faster in photopic adaptation when receiving high light intensity. Moreover, it causes a higher cone index and eye fish changed to fully adapted condition [9], [15-17].

The use of LED light also influenced the pattern of swimming behaviour. In the dark conditions, fish swim randomly in all parts of the observation tank. Swimming patterns were inconsistent and irregular. The light treatment caused changes in the behaviour of swimming pattern. Although at the low intensity, the different color of LED lamp did not affect the behaviour patterns. However, the radius of the swimming pattern towards the center of the lighting area was different under different color illumination. The radius of the swimming pattern with green LED is closer to the main light zone than blue LED. In the blue light, the radius and the swimming pattern were also outside of the main light zone. The main swimming area of the blue LED was in the range of 30-150 μW/cm². The fish swimming pattern dominantly found in the zone with an intensity of <3.0 μW/cm² or outside the main light zone with the green LED as presented in figure 4.
Figure 2. Fish proportion at observation zone.

Figure 3. Cone index of yellowstripe scad at different colours and intensity of LED lamp, Dark  Green  Blue.
The swimming pattern at the medium light intensities was similar to low light intensities. Meanwhile, the fish swim into the center of the lighting area in each color. The proportion of its pattern within the blue LED was higher than inside the green LED. Fish was more concentrated in under the green light. The swimming pattern was more consistent and focused on the main area of the lighting zone with a smaller radius to the lighting zone as presented in figure 5.

Fish swimming patterns with blue LED tend to be random and inconsistent at high intensities. More consistent pattern occurred in green LED where fish swim with a small radius and increasingly concentrated in the lighting area as shown in figure 6. The scads showed a consistent response to green LED, thus increasing visual acuity and influencing the ability to maintain the characteristics and swimming patterns during observation. Exposure to a green light within 30 minutes also did not indicate the existence of stress behavior which was marked by sudden changes in swimming behavior, so that it had no effect on the swimming pattern behavior. This result is similar to other research. The application of green LED lights in the *Gadus morhua, Scophthalmus maximus, Chrysiptera parasema* and *Salmo salar* is also able to reduce the level of stress experienced [18-21].

**Figure 4.** Swimming pattern behaviour on blue and green LED at a low intensity.
Figure 5. Swimming pattern behaviour on blue and green LED at medium intensity.
4. Conclusion

The application of green LED as a light source on fishing activity is better than the blue LED due to optimum retinal adaptation, consistency of swimming behavior and small radius swimming pattern toward to main light zone. The optimum intensity was ranged 3 - 23 μW/cm².

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Figure 6. Swimming pattern behavior on blue and green LED at high intensity.
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