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IJAB-20-0048 Editor assigned

2 messages

Muhammad Kasib KHAN <kasibdadra@hotmail.com>
To: "adisusanto@untirta.ac.id" <adisusanto@untirta.ac.id>

1 February 2020 at 12:45

Ms No.: **IJAB-20-0048**Title: **The behavioral and retinular response of Scad *Selaroides leptolepis* to low light emitting diode**

Dear Author(s),

Reference to above mentioned manuscript, I have been assigned as editor to your manuscript. The current status of your manuscript is "Reviewers Assignment Pending".

For further correspondence related to your manuscript, you can contact me directly.

Thank you for considering IJAB for submission of your manuscript.

Best Regards

Dr. Muhammad Kasib Khan | D.V.M., M.Sc., Ph.D. (HZAU, China)**Assistant Professor | Department of Parasitology****Editor | International Journal of Agriculture and Biology (IF=0.869)****University of Agriculture, Faisalabad | Pakistan****Ph Office: +92 (41) 9201106 | Mobile: +92 (334) 6656066****Email: mkkhan@uaf.edu.pk | kasibdadra@hotmail.com****Skype ID: kasibdadra | Researcher ID: C-8430-2013 | Google Scholar ID : [mkkhan](#) | QQ No. : 1363265136**

Adi Susanto, S.Pi., M.Si <adisusanto@untirta.ac.id>
To: Muhammad Kasib KHAN <kasibdadra@hotmail.com>

1 February 2020 at 14:00

Dear Dr. Khan

Thank you for your information.

We hope the review process will already done soon.

Kind regards.

[Quoted text hidden]



Adi Susanto, S.Pi., M.Si <adisusanto@untirta.ac.id>

MS IJAB-20-0048 Minor revision

3 messages

Muhammad Kasib KHAN <kasibdadra@hotmail.com>
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6 March 2020 at 12:04

Dear author(s),

The manuscript IJAB-20-0048 has been evaluated by the reviewers and a minor revision is suggested. Please find attached herewith evaluation sheet containing reviewers' comments and a manuscript file with page numbers for understanding of comments of reviewer(s). Please note that the one of the reviewers also commented in the attached manuscript file which needs to be addressed in the revision. The author(s) are advised to make changes in the attached manuscript using track changes and submit marked-up file along with reviewer's response on a separate sheet.

Best Regards

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3 attachments **Evaluation IJAB-20-0048.pdf**
95K **Manuscript IJAB-20-0048.docx**
4390K **Manuscript IJAB-20-0048.docx**
4390K

Adi Susanto, S.Pi., M.Si <adisusanto@untirta.ac.id>
To: Muhammad Kasib KHAN <kasibdadra@hotmail.com>

6 March 2020 at 12:53

Dear Dr. Khan

Thank you very much for your information.
We will address suggestion from the reviewers to our manuscript.

Best regards.

[Quoted text hidden]

Adi Susanto, S.Pi., M.Si <adisusanto@untirta.ac.id>
To: Muhammad Kasib KHAN <kasibdadra@hotmail.com>

11 March 2020 at 11:10

Dear Dr. Khan



Manuscript Evaluation Report

MS No: IJAB-20-0048

Title: The behavioral and retinular response of Scad *Selaroides leptolepis* to low light emitting diode

Author(s): Sugeng Hari Wisudo, Adi Susanto, Mochammad Riyanto, Mulyono Sumitro Baskoro, Fis Purwangka

COMMENTS

Reviewer 1

In generally, it is a good manuscript and well prepared.

Title

Please consider to change to “The behavior and retinular response of scad, *Selaroides leptolepis* to the different colors of light emitting diode.”

Abstract

Please consider to add “The combination of both green and white LED can be more effective light attractant to scad for lift net fishing” around the end of the abstract.

Keyword

Please consider to add “behavioral response, retinular response, *Selaroides leptolepis*, LED fishing”

Introduction

- Line 51-52, how prominent/important of the lift-net fishing in Indonesia? What are the target species of the life net? Why the scad was interested/focused in this study?... It is pretty good if the authors can show some catch statistics and others.
- Line 55, what is the CFL lamps?

Materials and Methods

Regarding the experiment conditions, for example the tank size (150x200x50 cm) and the water depth (30 cm, real fishing ground about 10 m you mentioned) and so on, how the size and depth can be accepted for such a kind like this experiment particularly in the view point of the fish schooling observations for the pelagic fish as scad? Please explain clearly or add some references to make clear that the tank conditions/methods can be accepted for the experiment.

Discussions

Good discussions!

- Line 249, Fig 7, please try to discuss more why the swimming patterns of the scad in the green and orange LED had similar tendencies (b &d) but quite different from white LED (d)?
- Regarding the lift net fishing operation, from the results of behavioral and reitnular response of this study, besides the schooling and swimming patterns of the scad, are there any good points to apply for improving the catch efficiency or better understanding of the capture process?

It was a good research work and the manuscript was well prepared, so it should be accepted with minor revisions.

Reviewer 2:

The paper is in good condition. However, some reviews must be done especially in reference part.

Suggestions have been included in manuscript file.

DECISION

Minor revision

Reviewer 1

No	Reviewer Comment	Revision
1	Please consider to change to “The behavior and reticular response of scad, <i>Selaroides leptolepis</i> to the different colors of light emitting diode.”	Already revised in Title The behaviour and reticular response of Yellowstripe scad, <i>Selaroides leptolepis</i> to the different colors of light emitting diode
2	Please consider to add “The combination of both green and white LED can be more effective light attractant to scad for lift net fishing” around the end of the abstract	We have revised in Abstract in Line 40-41
3	Please consider to add “behavioral response, reticular response, <i>Selaroides leptolepis</i> , LED fishing”	We have revised in keywords in Line 42
4	Line 51-52, how prominent/important of the lift-net fishing in Indonesia? What are the target species of the life net? Why the scad was interested/focused in this study? It is pretty good if the authors can show some catch statistics and others.	Thank you very much for your question and suggestion to improve this paper, we have added the information regarding your comment in 53-58 with catch statistics and proportion of scad in lift net fisheries
5	Line 55, what is the CFL lamps	We have added the information regarding CFL lamps in Line 58
6	Regarding the experiment conditions, for example the tank size (150x200x50 cm) and the water depth (30 cm, real fishing ground about 10 m you mentioned) and so on, how the size and depth can be accepted for such a kind like this experiment particularly in the view point of the fish schooling observations for the pelagic fish as scad? Please explain clearly or add some references to make clear that the tank conditions/methods can be accepted for the experiment.	Thank you for the comment: All experimental setup is following to previous research, especially from Marchesan et al. (2005), Pignatelli et al. (2011), Cha et al. (2012), and Utne-Palm et al. (2018). We have revised in Line 93-94
7	Line 249, Fig 7, please try to discuss more why the swimming patterns of the scad in the green and orange LED had similar tendencies (b &d) but quite different from white LED (d)?	Thank you for your suggestion: we added some discussion regarding the swimming pattern of the scad to the LED lamps in Line 283-300.
8	Regarding the lift net fishing operation, from the results of behavioural and reticular response of this study, besides the schooling and swimming patterns of the scad, are there any good points to apply for improving the catch efficiency or better understanding of the capture process?	We have added the discussion regarding on your suggestion in Line 312-321

Reviewer 2

No	Reviewer Comment	Revision
1	Scad, please write in complete common name	Thank you very much for your suggestion, we have revised in title to Yellowstripe scad
2	Matsushita and Yamashita, 2012: This one was not found in References	We have added the reference as your suggestion in Line 383-385
3	Where the location of the laboratory? At a laboratory? At your university?	We have added the information of the laboratory in IPB University. We have revised in Line 87-88
4	Nguyen and Tran, 2015 This one was not found in References	We have added the reference as your suggestion in Line 405-406

Received 09 Jan.

Running title: ~~Behavioral~~Behavioural and ~~retinular~~reticular response of Scad
The ~~behavioral~~behavioural and ~~retinular~~reticular response of Scad, *Selaroides leptolepis*
[SG1]to low light emitting diode

Novelty statement

In this manuscript, we describe the novel approach to design efficient and effective fishing lamp using low light LED lamp due to behavioral and retinular response of fish. The new approach was conducted to determine the light intensity threshold and colour preference of fishing lamp for concentrating and focusing the fish at catchable area. We found that the white LED is suitable enough for attract the fish and the green one is effective for focusing and control the ~~behavior~~behaviour of fish in catchable area.

Abstract

The objective of this research is to ~~analyze~~analyse the ~~behavioral~~behavioural and the ~~retinular~~reticular response of scad through both laboratory observation and a fishing trial as scientific evidence to designate the effective LED light for lift net fisheries. Different colors were used in a laboratory experiment, including green, orange, and white LED. Laboratory experiment were conducted in three illumination levels, low, medium, and high intensity. Light intensity strongly affects fish ~~behavior~~behaviour and activity. Green light improves the vision of fish and the ability to maintain schooling ~~behavior~~behaviour. Using the same LED colors, the adaptation stage of cone cells increases as the light intensity grows. The exposure of high-intensity LEDs rapidly induces the cone cells into photopic adaptation. The same results are found in both fishing trials and laboratory observations. Regarding the ability to induce good light adaptation and stable swimming patterns, it is argued that green LED lamps are preferable to substitute fluorescent lamps currently used in the lift net fishing.

Keywords: adaptation, cone, intensity, lift net

Introduction

Light fishing is one of the most effective and advanced fishing methods to catch commercial pelagic species in both small-scale and large-scale fisheries. In the common fishing practices, fishers use either fixed or mobile fishing gear (Ben-Yami, 1976; Wang et al., 2010; Yamashita et al., 2012; Ortiz et al., 2016; Solomon and Ahmed, 2016; Nguyen et al., 2017; Nguyen and Winger 2019). However, artificial light consumes a significant amount of energy due to the use of numerous high powered lamps. One of the prominent small-scale light fishing practices in Indonesia is lift net fishing, which uses a fluorescent lamp as the typical light sources. The application of fluorescent lamp in lift net fishing has several problems, including short lifetime, high fuel consumption and low effectiveness to control the fish ~~behavior~~behaviour during fishing operation. Fishing operation using CFL lamps in fixed lift net consumed 5.20 to 7.00 l/night (mean 6.33 ±0.54 SD) while light emitting diode (LED) lamps consumed 3.30 to 5.30 l/night (mean 4.11±0.61 SD). However, it is argued that

45 differences in fluorescent lamp quantities and wattages significantly affect the fishers'
46 income (Susanto et al. 2017a).

47 Light emitting diode as the latest efficient light source technology, has the potential to
48 be applied as an artificial light source for fishing with light (An et al., 2017; Susanto et al.,
49 2017b; Nguyen and Winger 2019). This lamp provides the maximum illumination power
50 combined with lower energy consumption, longer lifetime, higher efficiency, better
51 chromatic performance, and lower environmental impact compared to traditional lighting
52 technology (Matsushita et al., 2012; Matsushita and Yamashita, 2012^[SG2]; Yamashita et al.,
53 2012; Breen and Lerner, 2013; Hua and Xing, 2013; Yeh et al., 2014; An et al., 2017;
54 Nguyen and Winger 2019). Furthermore, the light distribution of LEDs, colour and intensity
55 considerably affect fish behavioralbehavioural and retinularreticular response. Therefore,
56 understanding the behaviorbehaviour of target species in response to LEDs is an important
57 step to develop an efficient LEDs for lift net fisheries.

58 We illuminate scad (*Selairoides leptolepis*) by three different low powered LED light
59 sources including green, orange, and white lamps, as well as dark conditions to investigate
60 the behavioralbehavioural and retinular response. Furthermore, in order to determine the
61 LEDs performance for lift net fishing, we focused to construct the basic evidence regarding
62 the behavioral and the retinular response of scad through fishing trial. This information is
63 important to develop efficient and effective LEDs for lift net fishing in Indonesia.

64

65 **Materials and Methods**

66

67 **Fish and Tank Experiment**

68 For the laboratory experiment, the behaviorbehaviour monitoring was conducted in a black
69 fiberglass of rectangular prisms open tank (150W x 200L x 50H cm) and the water depth was
70 maintained at 30 cm. ^[SG3]The tank was placed in the controlled dark room to secure no natural
71 light existing during experiment. The tank was divided into six zones and marked at the
72 bottom in 10 cm intervals as the calibration scale (Fig. 1). Being closer to the light source
73 zone 3 and 4 are light zones (bright zones), while zone 1,2,5, and 6 are the dark zones. The
74 LEDs were assembled approximately 20 cm from sea water level at experiment tank.

75 The running water systems were installed to ensure the fish remain alive in optimum water
76 quality during observation. Scad (12.45 cm in average total length (TL), N=60) were
77 collected using a guiding barrier at Banten Bay and transferred to the laboratory for
78 adaptation and acclimatization period for seven days. The scad were exposed to normal daily
79 light-dark cycle (12 L: 12 D, sun light were used in daytime). The water salinity in all tanks
80 was maintained at 30-33 ‰, the temperature was at 29-31°C and dissolved oxygen ranged
81 from 5.9-6.1 mg/L. Before and after the experiments, fish were fed two times per day with
82 *Artemia sp.* Therefore, the behavior experiment was conducted on static water circulation.
83 All of the experiments were performed during the night to minimize the influence of light
84 from any endogenous circadian effects on the fish behavioralbehavioural and
85 retinularreticular responses.

86 **Light Source and BehavioralBehavioural Methods**

87 Lamps were assembled using four dual inline package (DIP) LEDs (Shenzhen Yuliang
88 Optoelectronics Technology Co. Ltd) mounted on the metal housing (11L x 5W x 7H cm),

89 powered by 4 V DC supply. The experiments were conducted in three colors of LEDs i.e.
90 green [approximate peak wavelength = 565 nm], orange [approximate peak wavelength = 600
91 nm], and white [approximate peak wavelength = 450 nm and 545 nm]. Therefore, each of
92 which consists of three illumination levels i.e. 20, 35, 50 lux. Light intensities were measured
93 using ILT 5000 research radiometer at 15 cm distance bellowed sea water level of the tank.
94 The intensity of green LEDs at 20 lux, 35 lux, and 50 lux is $24 \mu\text{W}\cdot\text{cm}^{-2}$, $54 \mu\text{W}\cdot\text{cm}^{-2}$, 90
95 $\mu\text{W}\cdot\text{cm}^{-2}$, respectively. In the same order of illumination level, the intensity for orange LEDs
96 was $20 \mu\text{W}\cdot\text{cm}^{-2}$, $21 \mu\text{W}\cdot\text{cm}^{-2}$, and $24 \mu\text{W}\cdot\text{cm}^{-2}$ while for the white LEDs was $15 \mu\text{W}\cdot\text{cm}^{-2}$, 76
97 $\mu\text{W}\cdot\text{cm}^{-2}$, and $94 \mu\text{W}\cdot\text{cm}^{-2}$.

98 The order of the experimental procedures is as follows. Firstly, before being tested 30 scad
99 were left at the experimental tank at least three days to acclimate, and were subjected to a 12
100 L:12 D photoperiod (light from 06:00 to 18:00; dark from 18:00 to 06:00). Ambient
101 illumination at 15 cm deep below seawater-level was about $16 \text{ nW}\cdot\text{cm}^{-2}$ in light conditions.
102 All experimental sessions started at 19:00 and ended at 22:00. Secondly, before the
103 experiment was started and between each experiment, fish were kept in the dark state for 30
104 minutes to ensure their retina in a scotopic condition. Subsequently, each lamp was turned on
105 for 30 minutes to allow fish to respond and adapt to the light. Visual observation and video
106 recording using the infrared camera were conducted during the dark and lighted conditions.
107 Three replications were conducted for each experiment (Marchesan et al., 2005). A total of
108 540 minutes of video recording was analyzed for each color to define fish proportion, scad
109 swimming speed around illumination zone, mean of nearest [neighborneighbour](#) distance
110 (MNND), and swimming pattern of the fish schooling.

111 **Retinular Response to Irradiance Changes**

112 We used eighteen fish for the retinal adaptation experiment using the following procedure.
113 Firstly, two fish were taken from the storage tank and placed in a cylinder tank with diameter
114 50 cm and height 43 cm. After 30 minutes set in the dark state, each LED lamp was
115 illuminated for approximately 30 min, and at the end of each treatment, eye specimens from
116 both fish were collected. Subsequently, each specimen was fixed in Bouin's solution and
117 infiltrated with paraffin. Tissue samples were cut in cross-sections of 4-6 μm thickness and
118 were stained with [hematoxylinhaematoxylin](#) and eosin for examination under the microscope.
119 This histological process followed the procedures from Arimoto et al. (2010) and Jeong et al.
120 (2013).

121 **Fishing Experiment**

122 The result of laboratory experiment was applied to define the suitable LEDs color for the
123 fishing trial which was conducted using a fixed lift net in Banten Bay during peak fishing
124 season on August 2018. The fishing trial was conducted at 10 m water depth as common
125 fishing ground in Banten Bay. According to the laboratory experiment, scad are especially
126 responsive to white and green LEDs. Therefore, both lamps were compared to a fluorescent
127 lamp, the light source used in the existing lift net fishing. We conducted the fishing
128 experiment using 50 W of a fluorescent lamp (typical lamp for lift net fishing) and 1.4 W of
129 LEDs due to the similar light output in the seawater column ($12\text{-}15 \mu\text{W}\cdot\text{cm}^{-2}$; measured using
130 ILT 5000 at 1 m below sea water). Ten fish were collected from each lamp making it 30 fish
131 in total. Subsequently, all fish's eyes went through the histological procedures, followed by
132 the examination of retinular adaptation under the microscope.

133 **Data Analysis**

134 In order to determine the degree of fish preference on each light stimulus, the proportion of
135 fish at each zone was ~~analyzed~~~~analysed~~ by counting the number of gathered fish in each zone
136 per minute observation (Kim and Mandrak, 2017). Social ~~behavior~~~~behaviour~~ was determined
137 by the mean nearest ~~neighbor~~~~neighbour~~ distance (MNND), which is the average of the planar
138 distances between each fish (head) and its closest ~~neighbor~~~~neighbour~~ (Parrish et al., 2002). It
139 was used to define the effect of different colors and intensity of schooling characteristics of
140 fish (Torisawa et al., 2007; Jolles et al., 2017). The MNND was ~~analyzed~~~~analysed~~ using
141 images that converted from the movie at the beginning (< 10 min), intermediate (11-20 min),
142 and the end of observation (21-30 min). The distance was analyzed with Kinovea 0.8.15 at
143 the center head of fish (Fig 2).

144 The degree of retinal light adaptation was represented in the adaptation ratio (%) (Arimoto et
145 al., 2010), which was calculated by $(B/A) \times 100$ (%), where A (μm) represents the distance
146 between the limiting membrane and the surface of the retina, and B (μm) represents the
147 migration of cone cells when it was stimulated by light. A and B were measured using
148 photomicrographs (Fig. 3). Swimming patterns at both LEDs colors and irradiance levels
149 were analyzed by using video tracking and trajectory software (Kinovea 0.8.15). Videotapes
150 were preliminary observed at 4X speed, to obtain the first qualitative swimming pattern and
151 the characteristic of each stage. In all experiments at every repetition, three dominant
152 swimming patterns from each LED's stimulus were chosen at the beginning, intermediate and
153 the end of the observation period. Parameters used to ~~analyze~~~~analyse~~ the swimming speed of
154 each pattern in total length per second (TL/s) are (1) time-lapse in each pattern; (2) number of
155 frames; (3) distance of each pattern. One-way ANOVA was applied to ~~analyze~~~~analyse~~ the
156 effect of different light stimuli (as explanatory variable) to proportion, MNND, and
157 swimming speed during observation (as response variable). Post-hoc comparisons, wherever
158 significance was found, were conducted using Tukey HSD test with the significance level
159 was set at $p < 0.05$.

160

161 **Results**

162

163 **Fish Preference to Light Stimuli**

164 The scad responded to the different light colors. At all illumination levels of each color, fish
165 showed high aggregation levels to the light zone. It was indicated by higher fish proportions
166 in zone 3 and 4 than dark zone as presented in Fig. 4. However, there was not a significant
167 difference in fish proportions at the dark condition for all zones (zone 1 to 6). The fish
168 proportion at the dark condition between the range 14 and 19%. The proportion tended to
169 increase related to the aggregating of light intensity, especially at the light zone. At the low
170 intensity, the proportion of fish at zone 3 and zone 4 was ranged between 22-32%. However,
171 the proportion was increased to 34-44% at high intensity level. There was also evidence to
172 suggest that light intensity (in the range 15-94 $\mu\text{W}\cdot\text{cm}^{-2}$) influences the behavior of the fish by
173 modifying swimming aggregations and preference in all LEDs colors.

174 **Relationship Between The Retinular Response and Irradiance Change**

175 The light adaptation of scad was influenced by LEDs color and intensity. The degrees of
176 adaptation of scad at scotopic adaptation are in the range between 26 and 34%. Adaptation

177 ratio increased with increasing light intensity at each LEDs color (Fig. 5a). The green LEDs
178 generated the highest adaptation ratio with a slight increase, range 83% (low intensity) to
179 93% (high intensity). However, the degree of light adaptation with orange and white LEDs
180 produced a various tendencies. The adaptation ratio of orange LEDs at low intensities is 32%,
181 and increase to 67% for the high light level. Furthermore, white LEDs generated higher
182 adaptation ratio than orange LEDs with the ratio between 73% (low intensity) to 92% (high
183 intensity).

184 **Swimming Behavior**

185 The swimming behavior of scad was strongly affected by light intensities at each LED color.
186 There was a significant decrease of MNND in all treatment with increasing intensity. The
187 farthest individual distance generated with orange LED was 14.8 cm, while the closest
188 distance was found at a white LED of 8.2 cm. In all experiments, the decline of MNND has a
189 relationship with increasing swimming speed. Scad has the fastest swimming speed at green
190 LED approximately $3.0 \text{ TL}\cdot\text{s}^{-1}$, while the lowest speed was initiated at low intensity of white
191 LED approximately $1.4 \text{ TL}\cdot\text{s}^{-1}$ (Fig. 6).

192 The different LED treatments also influenced the pattern of swimming behavior. In all
193 dark conditions, fish swam randomly around the experiment tank. There are inconsistent and
194 irregular swimming patterns of scad during the dark observation period. The light exposure
195 caused changes in swimming behavior. In low intensity, the different color of LEDs did not
196 affect the behavioral patterns. Moreover, the increasing light intensity induces the
197 transformed swimming pattern in all colors. The fish swam randomly and inconsistently at a
198 high intensity of the white LED. However, the scad showed a consistent response to orange
199 and green LED with different radii in swimming patterns. Its radius with green LED is closer
200 to the main light zone than orange LEDs, as presented in Figure 7. Moreover, there were
201 constant and stable swimming patterns related to the time elapsed at the green LEDs,
202 approximately after 20 minutes of observation. The specifics of fish swimming behavior are
203 presented in Table 1.

204 **Fishing Trials**

205 There are 1,082 scads were caught during fishing experiment. The light adaptation of the
206 retina collected during the fishing trial is shown in Fig 5b. The cone index was found to be
207 between the range of 78 and 91%. The green LED generated a higher mean adaptation ratio
208 (84%) than white LED (81%) and a fluorescent lamp (83%). However, there were no
209 significant differences in cone index from the sea experiment ($P>0.05$).

210

211 **Discussions**

212

213 The highest number of fish proportion in the bright observation zone indicated the scad as a
214 phototaxis fish that attracted by light. The proportion was superior to the bright zones.
215 However, these zones have a smaller area than shadow zones. There were significant
216 differences in the fish proportion between colors and intensities, whereas the proportion in
217 the bright zone at each color gradually increased with rising intensity. The brightness level
218 influences the level of fish activity. Thus, it would have been relevant to increase the fish
219 proportion in all bright zones (Marchesan et al., 2005; Utne-Palm et al., 2018). This condition
220 is an adaptation response to maintaining the formed characteristic of scad schooling behavior,

221 related to the exposure of light intensity in their environment (Woodhead, 1966; Martin and
222 Perez, 2006).

223 There were significant differences in light adaptation ratio between dark and light
224 state ($p < 0.05$). The degree of light adaptation ratio has a positive association with an increase
225 of light intensity (Susanto et al., 2017c). With all colors used in the experiment, the
226 adaptation stage of cone cells increases with expanding intensity. The exposure of high-
227 intensity LEDs induces the cone cells into photopic adaptation rapidly. Thus the light
228 adaptation ratio was increased (Tamura and Niwa, 1967; Nakano et al., 2006; Migaud et al.,
229 2007). The green LEDs generated the highest adaptation ratio of scad in all intensity levels.
230 Thus, it would have been relevant to conclude that the maximum sensitivity of the
231 Carangidae fish family, including scad, has a peak sensitivity between 494-500 nm (Munz
232 and McFarland, 1973).

233 Light intensity has prevailing influence on the visual ability of fish. However, scad's ability
234 to use vision to maintain the schooling characteristic during light level increases necessitates
235 phototaxis. Moreover, there were significant differences in swimming behavior, including
236 swimming patterns and MNND in the different light conditions, whereas the fish activity
237 increased with rising intensity. The MNND has a negative relationship with light intensity,
238 whereas the MNND decreased with increasing intensity levels. However, the swimming
239 speeds of scad showed different tendencies with MNND during expanding light levels. The
240 fish swam faster at the high intensity at all LED colors. The high intensity induced fish easier
241 to maintain the direction and orientation of their schooling, due to an increase in their
242 swimming speed at all treatments (Miyazaki et al., 2000). Similar tendencies were found at
243 the swimming speed of Atlantic salmon *Salmo salar*. Its speed was increased from 0.2 BL/s
244 to 0.5 BL/s related to the increase of the light level at sea cage observation (Hansen et al.,
245 2017).

246 The swimming patterns of scad in the green and orange LEDs have similar tendencies.
247 However, the swimming radius at the green LED was closer to the center of the light zone
248 than an orange LED. The fish have a proper response to green light due to an increase in
249 visual ability and significant influence to fish capability to maintain their schooling
250 characteristics. In one example of schooling during increased light intensity, increasing visual
251 ability influenced each individual, enabling them to maintain their distance and formation
252 relative to the rest of the school during swimming (Glass et al., 1986; McMahon and
253 Holanov, 1995; Miyazaki and Nakamura, 1990).

254 The light adaptation of scad from the fishing experiment has similar tendencies with
255 laboratory observations. The green LED generated a higher degree of adaptation than the
256 white LED and fluorescent lamp at the same intensity. The information on the reticular
257 response and adaptation to light source was utilized in studying the relationship between a
258 light fishing procedure, light color, and light intensity to develop an efficient use of the LED
259 fishing lamp (Jeong et al., 2013). In this research, we compare the characteristics of scad
260 swimming behavior, and light adaptation between experimental tanks and fishing trials to
261 determine the suitable low powered LED color as a light source when fishing. From these
262 results, the green LED, which induces good light adaptation and stable swimming patterns, is
263 suitable enough to substitute fluorescent lamps currently used in lift net fishing.

264 The combination in both green and white LED can be a more effective light attractant to scad
265 fishing at lift net fisheries. The white LED is useful when gathering scads and induces high
266 light adaptation. However, the swimming pattern of scad at white LED was random and
267 unstable, due to the light source having to change with green LED when focusing the fish at a
268 catchable area. The LED innovation as artificial light has several advantages. The LED
269 provides maximum illumination power, combined with minimum energy consumption, long
270 lifespan, high efficiency, better chromatic performance, and reduced environmental impact
271 compared to traditional lighting technology (Matsushita et al., 2012; Matsushita and
272 Yamashita, 2012; Yamashita et al., 2012; Breen and Lerner, 2013; Hua and Xing, 2013; Yeh
273 et al., 2014; Nguyen and Tran, 2015^[SG4]; An et al., 2017). However, further fishing trials are
274 recommended to validate the effectiveness of both white and green LED as a light stimulus
275 for gathering and focusing scad at lift net fisheries.

276

277 **Conclusions**

278

279 Present investigation showed the white LED is a suitable enough to attract fish to catchable
280 area while the green LED is an effective color for focusing and control behavior of scad in
281 catchable area. We conclude that combination of white and green LED can be a more
282 effective light attractant to scad fishing at lift net fisheries.

283

284 **Acknowledgments**

285

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287 The Republic of Indonesia through graduate team research grant number
288 1549/IT3.11/PN/2018.

289

290 **References**^[SG5]

291

292 An, Y.I., P. He, P., T. -Arimoto, T., U. J. Jang, U.J. 2017. Catch performance and fuel
293 consumption of LED fishing lamps in the Korea hairtail angling fishery. *Fish. Sci.*, 83: 343–
294 352.

295 Arimoto, T., Glass, C.W., Zhang, X. 2010. Fish vision and its role in fish capture. He, P.
296 (Eds), *Behavior of marine fishes: capture processes and conservation challenges*. Blackwell
297 Scientific, USA

298 Ben-Yami, M., 1976. *Fishing with light*. Fishing News Books, Oxford USA

299 Breen, M., Lerner, A. 2013. An introduction to light and its measurement when investigating
300 fish behaviour. Symposium on the Light session and the Topic Group Lights: ICES-FAO
301 Working Group on Fishing Technology and Fish Behaviour. May 6–10, Bangkok, Thailand

302 Glass, C.W., Vardle, C.S., Mojsiewicz, W.R. 1986. A light intensity threshold for schooling
303 in the Atlantic Mackerel *Scomber scombrus*. *J. Fish Biol.*, 29 (Suppl A): 71-81

304 Hansen, T.J., Fjellidal, P.G., Folkedal, O., Vågseth, T., Oppedal, F. 2017. Effects of light
305 source and intensity on sexual maturation, growth and swimming behaviour of Atlantic
306 Salmon in sea cages. *Aquac. Environ. Interact.*, 9: 193-204

307 Hua, L.T. and Xing, J. 2013. Research on LED fishing light. *Res. J. Appl. Sci, Eng. and*
308 *Technol.*, 5: 4138-4141

309 Jeong, H., Yoo, S., Lee, J., An, YI. 2013. The reticular responses of common squid
310 *Todarodes pacificus* for energy efficient fishing lamp using LED. *Renew. Energy.*, 54: 101-
311 104

312 Jolles, J.W., Boogert, N.J., Sridhar, V.H., Couzin, L.D., Manica, A. 2017. Consistent
313 individual differences drive collective behavior and group functioning of schooling fish.
314 *Current Biol.*, 27: 1-7

315 Kim, J. and Mandrak, N.E. 2017. Effects of strobe lights on the behaviour of fresh water
316 fishes. *Environ. Biol. Fish.*, 100: 1427-1434

317 Marchesan, M., Spoto, M., Verginella, L., Ferrero, E.A. 2005. Behavioural effects of
318 artificial light on fish species of commercial interest. *Fish. Res.*, 73: 171-185

319 Martin, R.S. and Perez, J.A.A. 2006. Cephalopods and fish attracted by night lights in coastal
320 shallow-waters, off Southern Brazil, with the description of squid and fish behavior. *Revista*
321 *de Etologia.*, 8: 27-34

322 Matsui, H., Takayama, G., Sakurai, Y. 2016. Physiological response of the eye to different
323 colored light-emitting diodes in Japanese flying squid *Todarodes pacificus*. *Fish. Sci.*, 82:
324 303-309

325 Matsushita, Y., Azuno, T., Yamashita, Y. 2012. Fuel reduction in coastal squid jigging boats
326 equipped with various combinations of conventional metal halide lamps and low-energy LED
327 panels. *Fish. Res.*, 125-126: 14-19

328 Matsushita, Y., Yamashita, Y. 2012. Effect of a stepwise lighting method termed “stage
329 reduced lighting” using LED and metal halide fishing lamps in the Japanese common squid
330 jigging fishery. *Fish. Sci.*, 78: 977-983

331 McMahan, T.E. and Holanov, S.H. 1995. Foraging success of largemouth bass at different
332 light intensities: implications for time and depth of feeding. *J. Fish. Biol.*, 46: 759-767

333 Migaud, H., Cowan, M., Taylor, J., Ferguson, H.W. 2007. The effect of spectral composition
334 and light intensity on melatonin, stress and retinal damage in post-smolt Atlantic salmon,
335 *Salmo salar*. *Aquac.*, 270: 390-404

336 Miyazaki, T. and Nakamura, Y. 1990. Single line acuity of 0-year-old Japanese parrotfish
337 determined by the conditioned reflex method. *Nippon Suisan Gakkaishi.*, 56: 887-892

338 Miyazaki, T., Shiozawa, S., Kogane, T., Masuda, R., Maruyama, K., Tsukamoto, K. 2000.
339 Developmental changes of the light intensity threshold for school formation in the striped
340 jack *Pseudocaranx dentex*. *Mar. Ecol. Prog. Ser.*, 192: 267-275

341 Munz, F.W. and McFarland, W.N. 1973. The significance of spectral position in the
342 rhodopsins of tropical marine fishes. *Vis. Res.*, 13: 1829-1874

343 Nakano, N., Kawabe, R., Yamashita, N., Hiraishi, T., Yamamoto, K., Nashimoto, K. 2006.
344 Color vision, spectral sensitivity, accommodation, and visual acuity in juvenile masu salmon
345 *Oncorhynchus masou masou*. *Fish. Sci.*, 72: 239-249

346 Nguyen, K.Q., Winger, P.D., Morris, C., Grant, S.M. 2017. Artificial lights improve the
347 catchability of snow crab (*Chionoecetes opilio*) traps. *Aquac. Fish.*, 2: 124–133

348 Nguyen, K.Q., Winger, P.D. 2019. Artificial light in commercial industrialized fishing
349 applications: a review. *Rev. in Fish. Sci. & Aquac.*, 27: 106-126

350 Ortiz, N., Mangel, J.C., Wang, J., Alfaro-Shigueto, J., Pingo, S., Jimenez, A., Suarez, T.,
351 Swimmer, Y., Carvalho, F., Godley, B.J. 2016. Reducing green turtle bycatch in small-scale
352 fisheries using illuminated gillnets: The cost of saving a sea turtle. *Mar. Ecol. Progr. Ser.*,
353 545: 251–259

354 Parrish, J.K., ~~S. V. Viscido~~, ~~D. S.V.~~, Grunbaum, ~~D.~~. 2002. Self-organized fish schools: an
355 examination of emergent properties. *Biol. Bull.*, 202: 296–305

356 Solomon, O.O., and O. O. Ahmed, ~~O.O.~~ 2016. Fishing with light: Ecological consequences
357 for coastal habitats. *Int. J. Fish. Aquac. Stud.*, 4: 474–483

358 Susanto, A., ~~R.~~ Irnawati, ~~R.~~, ~~Mustahal, Syabana~~, M. A. ~~Mustahal Syabana~~, 2017a. Fishing
359 efficiency of LED lamps for fixed lift net fisheries in Banten Bay Indonesia. *Turkish J. of*
360 *Fish. and Aqua. Sci.*, 17: 283-291

361 Susanto, A., Baskoro, M.S., Wisudo, S.H., Riyanto, M., Purwangka, F. 2017b. Seawater
362 battery with Al-Cu, Zn-Cu, Gal-Cu electrodes for fishing lamp. *Inter. J. of Renew. Energy*
363 *Res.*, 7: 1857-1868

364 Susanto, A., Fitri, A.D.P., Putra, Y., Sutanto, H., Alawiyah, T. 2017c. Respons dan adaptasi
365 ikan teri (*Stolephorus* sp.) terhadap lampu light emitting diode (LED). *Mar. Fish.*, 8: 39-49

366 Tamura, T. and Niwa, H. 1967. Spectral sensitivity and color vision of fish as indicated by S-
367 potential. *Comp. Biochem. Physiol.*, 22: 745-754

368 Torisawa, S., Takagi, T., Fukuda, H., Ishibashi, Y., Sawada, Y., Okada, T., Miyashita, S.,
369 Suzuki, K., Yamane, T. 2007. Schooling behaviour and retinomotor response of juvenile
370 Pacific bluefin tuna *Thunnus orientalis* under different light intensities. *J. of Fish Biol.*, 71:
371 411-420

372 Utne-Palm, A.C., Breen, M., Løkkeborg, S., Humborstad, O.B. 2018. Behavioural responses
373 of krill and cod to artificial light in laboratory experiments. *Plos One.*, 13: 1-17

374 Viscido, S.V. and Grünbaum, D. 2002. Self-organized fish schools: an examination of
375 emergent properties. *Biol. Bull.*, 202: 296–305

376 Wang, J. H., Fisler S., Swimmer, Y. 2010. Developing visual deterrents to reduce sea turtle
377 bycatch in gill net fisheries. *Mar. Ecol. Progr. Ser.*, 408: 241–250

378 Woodhead, P.M.J. 1966. The behaviour of fish in relation to light in the sea. *Oceanog. and*
379 *Marine Biol. Annu. Rev.*, 4: 337-403

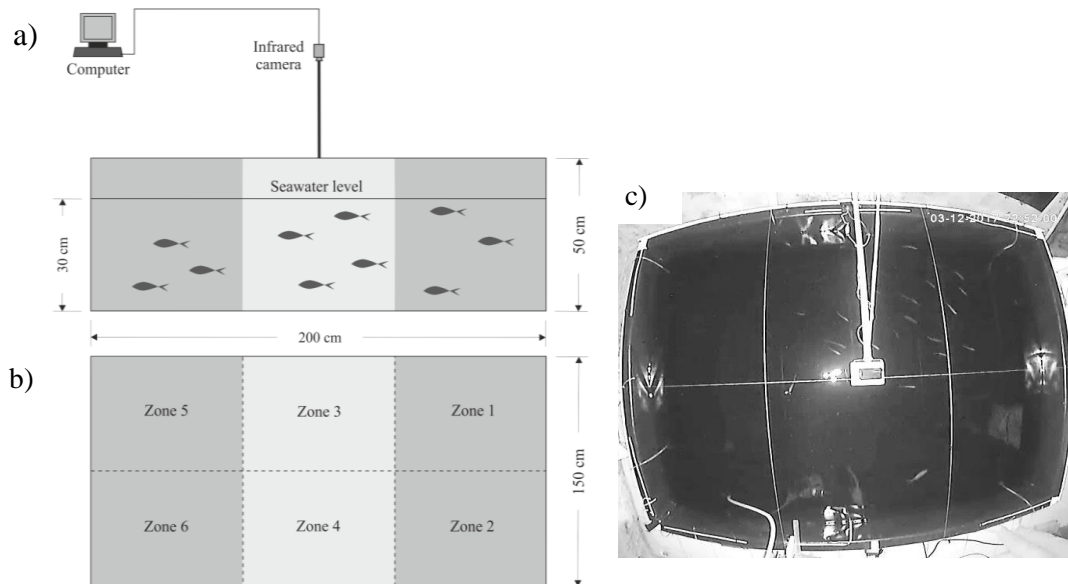
380 Yamashita, Y., Matsushita, Y., Azuno, T. 2012. Catch performance of coastal squid jigging
381 boats using LED Panels in combination with metal halide lamps. *Fish. Res.*, 113: 182–189

382 Yeh, N., Yeh, P., Shih, N., Byadgi, O., Cheng, T.C. 2014. Applications of light-emitting
383 diodes in researches conducted in aquatic environment. *Renew. Sustain. Energy Rev.*, 32:
384 611–618

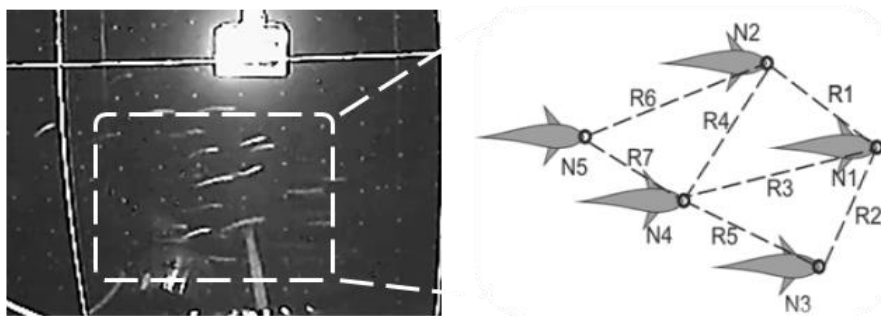
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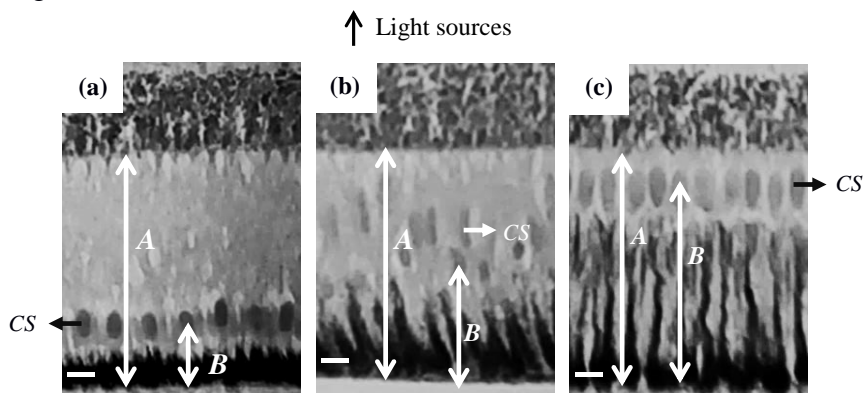
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 389 **Fig. 1:** The open tank experiment for the behavioral response. The side view of experimental
 390 tank set up (a), top view (b), and infrared camera view (c).

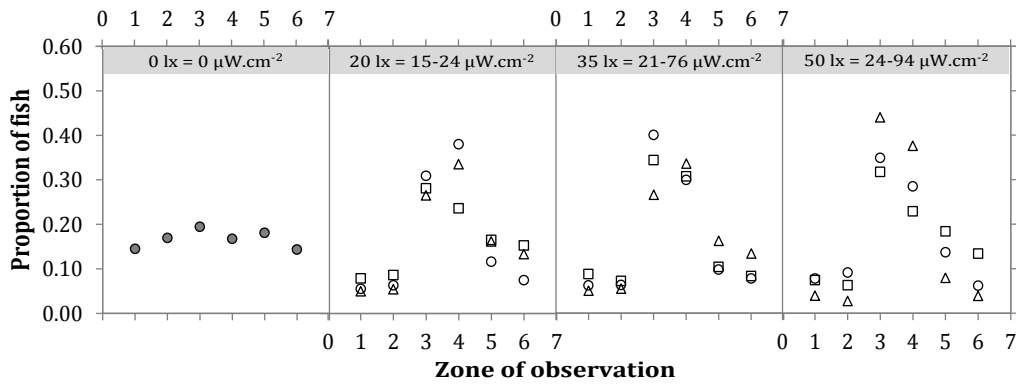


391
 392 **Fig. 2:** Illustration of NND method from the image recording. N1 to N5 represent the number
 393 of fish. R1 to R7 represent the planar distances between each fish (head) and its closest
 394 neighbor

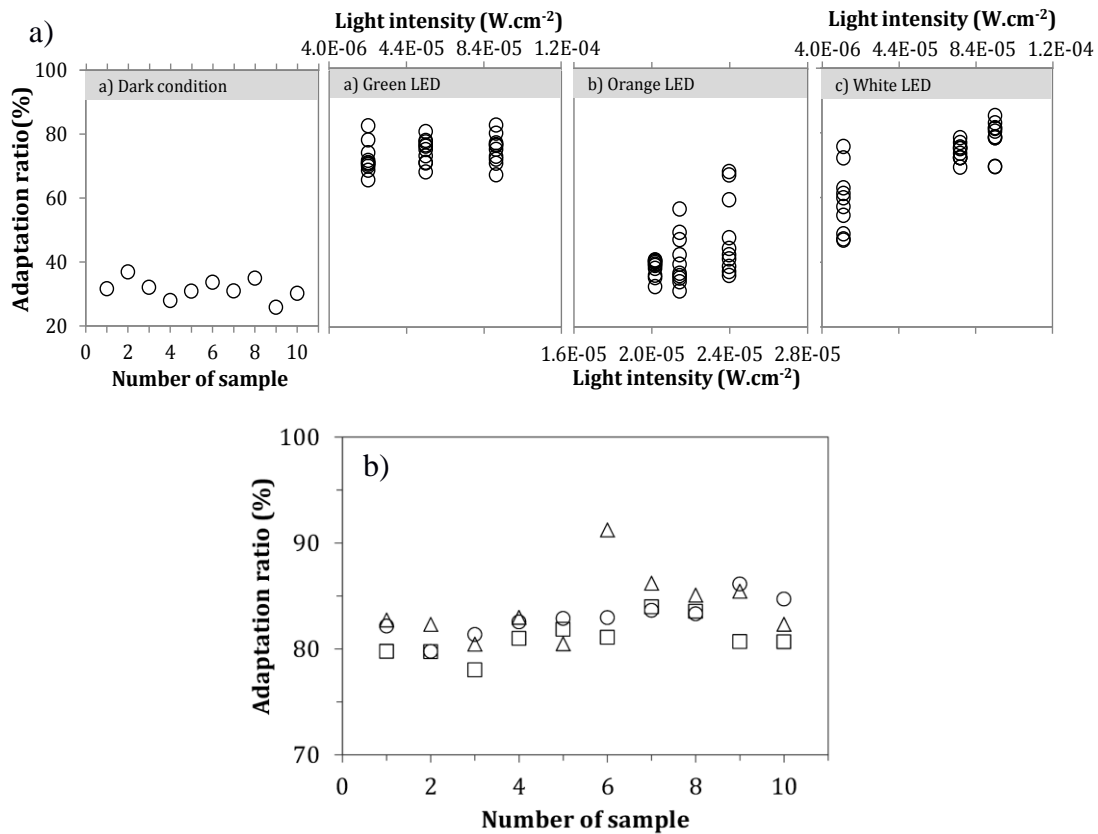


395
 396 **Fig. 3:** Photomicrographs show various states of retinal light adaptation of *Selaroides* sp. *A*
 397 thickness from the limiting membrane to the surface of the retina and *B* thickness of cone cell
 398 migration. **a.** Dark adapted, **b.** transitional stage, and **c.** light adapted. *CS:* cone cell. Scale bar
 399 = 10 μ m.

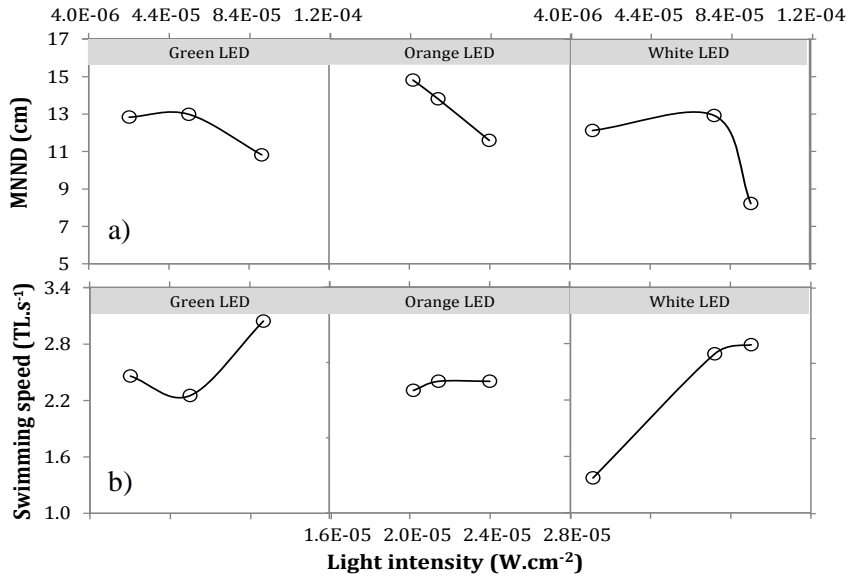
400



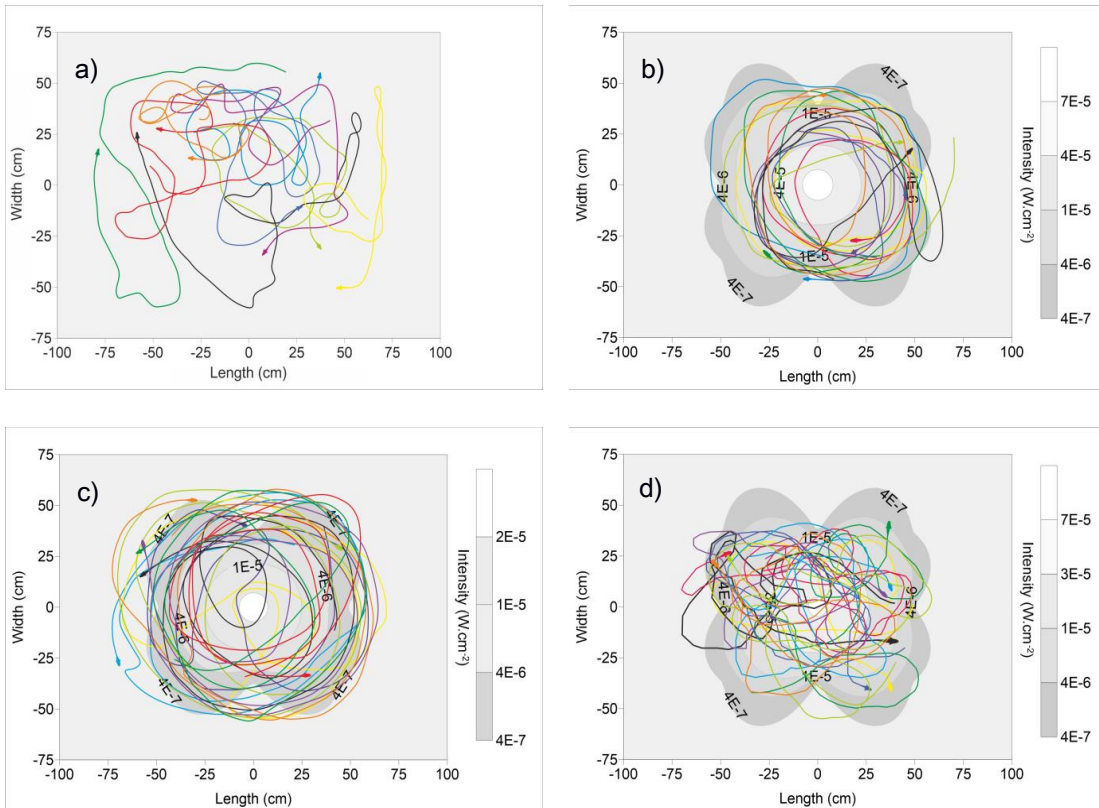
401
 402 **Fig. 4:** The proportion of fish related to the color and light intensity. The proportion of scad
 403 observed during replicated color treatments (green-circle; orange-square; white-triangle;) and
 404 dark condition (filled circle).
 405



406
 407 **Fig. 5:** The light adaptation of scad retina cells to different color and light intensity in
 408 laboratory experiment (a) and the light adaptation of the retina cells collected from the fishing
 409 experiment (b). The cone index of fluorescent-circle, white LED-square, and green LED-
 410 triangle.



411
 412 **Fig. 6:** The swimming behavior of scad to different LED colors and intensities. The mean
 413 nearest neighbor distances (a) and swimming speed (b).
 414



415
 416 **Fig.7:** The individual swimming pattern of scad in different color and LEDs intensity. The
 417 swimming pattern in dark condition (a), green LED (b), orange LED (c) white LED (d).
 418 Different fish are color-coded.
 419
 420
 421

422 **Table 1:** Fish behavior related to the time elapsed observation

Time elapsed (minute)	Fish Behavioral Response
0 - 5	There was no schooling and swimming behavior pattern at the beginning treatment. Fish swam in all directions due to orientation and adaptation period related to the light color and intensity at the experimental tank.
6 - 10	The fish started to school with several swimming patterns. However, there were an unstable direction and swimming speed.
11 - 20	There was a stable and consistent swimming pattern. The swimming speed was increased related to time-lapse.
21 - 30	The swimming patterns were stable and consistent with steady swimming speed. The radius of swimming was stable and relatively closest to the center of the light zone.

423



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MS IJAB-20-0048 Accepted

1 message

Muhammad Kasib KHAN <kasibdadra@hotmail.com>

16 March 2020 at 15:20

To: "Adi Susanto, S.Pi., M.Si" <adisusanto@untirta.ac.id>, Editorial Office Ijab <editorijab@yahoo.com>

Dear Author(s),

I am pleased to inform you that your manuscript IJAB-20-0048 has been accepted for publication in IJAB. Soon, you will receive email from editorial office of IJAB containing instructions for further proceedings. Thank you for considering IJAB to publish your valuable research.

Dear Editorial Officer,

Please find attached herewith the final draft of manuscript IJAB-20-0048 for publication process.

Best Regards

Dr. Muhammad Kasib Khan | D.V.M., M.Sc., Ph.D. (HZAU, China)

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From: Adi Susanto, S.Pi., M.Si <adisusanto@untirta.ac.id>**Sent:** Sunday, March 15, 2020 3:45 AM**To:** Muhammad Kasib KHAN <kasibdadra@hotmail.com>**Subject:** Re: MS IJAB-20-0048 Minor revision is again suggested

Dear Dr Khan

Here I attached the revised manuscript, especially in reference list as you requested.

Please feel free to inform me if there is anything incorrect.

Best regards

Adi Susanto

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Website: <http://untirta.ac.id>
-----On Sat, 14 Mar 2020 at 13:42, Muhammad Kasib KHAN <kasibdadra@hotmail.com> wrote:

Dear Adi Susanto,

The revised manuscript IJAB-20-0048 has been evaluated and i am pleased to inform you that it still needs minor revision in the following areas:

1. The references in the list need to be formatted according to journal's requirement.

1 **Manuscript type:** Original Research Article

2 **Running title:** Behaviour and retinular response of Yellowstripe scad

3 **The behaviour and retinular response of Yellowstripe scad, *Selaroides leptolepis* to**
4 **the different colors of light emitting diode**

5
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7 **Baskoro¹, Fis Purwangka¹**

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18
19 **Novelty statement**

20 In this manuscript, we describe the novel approach to design efficient and effective
21 fishing lamp using low light LED lamp due to behavioural and retinular response of
22 fish. The new approach was conducted to determine the light intensity threshold and
23 colour preference of fishing lamp for concentrating and focusing the fish at catchable
24 area. We found that the white LED is suitable enough for attract the fish and the green
25 one is effective for focusing and control the behaviour of fish in catchable area.

26
27 **Abstract**

28 The objective of this research is to analyse the behavioural and the retinular response of
29 scad through both laboratory observation and a fishing trial as scientific evidence to
30 designate the effective LED light for lift net fisheries. Different colors were used in a
31 laboratory experiment, including green, orange, and white LED. Laboratory experiment
32 were conducted in three illumination levels, low, medium, and high intensity. Light
33 intensity strongly affects fish behaviour and activity. Green light improves the vision of

34 fish and the ability to maintain schooling behaviour. Using the same LED colors, the
35 adaptation stage of cone cells increases as the light intensity grows. The exposure of
36 high-intensity LEDs rapidly induces the cone cells into photopic adaptation. The same
37 results are found in both fishing trials and laboratory observations. Regarding the ability
38 to induce good light adaptation and stable swimming patterns, it is argued that green
39 LED lamps are preferable to substitute fluorescent lamps currently used in the lift net
40 fishing. The combination of both green and white LED can be more effective light
41 attractant to Yellowstripe scad for lift net fishing.

42 **Keywords:** behavioural response, LED fishing, reticular response, *Selaroides leptolepis*

43

44

45 **Introduction**

46 Light fishing is one of the most effective and advanced fishing methods to catch
47 commercial pelagic species in both small-scale and large-scale fisheries. In the common
48 fishing practices, fishers use either fixed or mobile fishing gear (Ben-Yami 1976; Wang
49 *et al.* 2010; Yamashita *et al.* 2012; Ortiz *et al.* 2016; Solomon and Ahmed 2016;
50 Nguyen *et al.* 2017; Nguyen and Winger 2019). However, artificial light consumes a
51 significant amount of energy due to the use of numerous high powered lamps. One of
52 the prominent small-scale light fishing practices in Indonesia is lift net fishing, which
53 uses a fluorescent lamp as the typical light sources. Fish production of lift net fishing in
54 2017 reached 48% from total production of small-scale light fishing in Indonesia
55 (Ministry of Marine Affairs and Fisheries Republic of Indonesia 2018). The main
56 targets of lift net fishing are anchovy, scad, sardinella and squid, which proportion of
57 scad ranged between 10-45% from the total catch (Guntur *et al.* 2015; Rudin *et al.*
58 2017). The application of fluorescent lamp in lift net fishing has several problems,

59 including short lifetime, high fuel consumption and low effectiveness to control the fish
60 behaviour during fishing operation. Fishing operation using fluorescent lamps in fixed
61 lift net consumed 5.20 to 7.00 l/night (mean 6.33 ± 0.54 SD) while light emitting diode
62 (LED) lamps consumed 3.30 to 5.30 l/night (mean 4.11 ± 0.61 SD). However, it is
63 argued that differences in fluorescent lamp quantities and wattages significantly affect
64 the fishers' income (Susanto *et al.* 2017a).

65 Light emitting diode as the latest efficient light source technology, has the
66 potential to be applied as an artificial light source for fishing with light (An *et al.* 2017;
67 Susanto *et al.* 2017b; Nguyen and Winger 2019). This lamp provides the maximum
68 illumination power combined with lower energy consumption, longer lifetime, higher
69 efficiency, better chromatic performance, and lower environmental impact compared to
70 traditional lighting technology (Matsushita *et al.* 2012; Matsushita and Yamashita 2012;
71 Yamashita *et al.* 2012; Breen and Lerner 2013; Hua and Xing 2013; Yeh *et al.* 2014; An
72 *et al.* 2017; Nguyen and Winger 2019). Furthermore, the light distribution of LEDs,
73 colour and intensity considerably affect fish behavioural and reticular response.
74 Therefore, understanding the behaviour of target species in response to LEDs is an
75 important step to develop an efficient LEDs for lift net fisheries.

76 We illuminate scad (*Selairoides leptolepis*) by three different low powered LED
77 light sources including green, orange, and white lamps, as well as dark conditions to
78 investigate the behavioural and reticular response. Furthermore, in order to determine
79 the LEDs performance for lift net fishing, we focused to construct the basic evidence
80 regarding the behavioural and the reticular response of scad through fishing trial. This
81 information is important to develop efficient and effective LEDs for lift net fishing in
82 Indonesia.

83 **Materials and Methods**

84 **Fish and Tank Experiment**

85 For the laboratory experiment, the behaviour monitoring was conducted in a black
86 fiberglass of rectangular prisms open tank (150W x 200L x 50H cm) and the water depth
87 was maintained at 30 cm. The tank was placed in the controlled dark room at State
88 College of Fisheries Serang City, to secure no natural light existing during experiment.
89 The tank was divided into six zones and marked at the bottom in 10 cm intervals as the
90 calibration scale (Fig. 1). Being closer to the light source zone 3 and 4 are light zones
91 (bright zones), while zone 1,2,5, and 6 are the dark zones. The LEDs were assembled
92 approximately 20 cm from sea water level at experiment tank. The experimental setup
93 following the research from Marchesan *et al.* (2005), Pignatelli *et al.* (2011), Cha *et al.*
94 (2012), and Utne-Palm *et al.* (2018).

95 The running water systems were installed to ensure the fish remain alive in
96 optimum water quality during observation. Scad (12.45 cm in average total length (TL),
97 N=60) were collected using a guiding barrier at Banten Bay and transferred to the
98 laboratory for adaptation and acclimatization period for seven days. The scad were
99 exposed to normal daily light-dark cycle (12 L: 12 D, sun light were used in daytime).
100 The water salinity in all tanks was maintained at 30-33 ‰, the temperature was at 29-
101 31°C and dissolved oxygen ranged from 5.9-6.1 mg/L. Before and after the
102 experiments, fish were fed two times per day with *Artemia sp.* Therefore, the
103 behaviour experiment was conducted on static water circulation. All of the experiments
104 were performed during the night to minimize the influence of light from any
105 endogenous circadian effects on the fish behavioural and reticular responses.

106

107

108 **Light Source and Behavioural Methods**

109 Lamps were assembled using four dual inline package (DIP) LEDs (Shenzhen Yuliang
110 Optoelectronics Technology Co. Ltd) mounted on the metal housing (11L x 5W x 7H
111 cm), powered by 4 V DC supply. The experiments were conducted in three colors of
112 LEDs i.e. green [approximate peak wavelength = 565 nm], orange [approximate peak
113 wavelength = 600 nm], and white [approximate peak wavelength = 450 nm and 545
114 nm]. Therefore, each of which consists of three illumination levels i.e. 20, 35, 50 lux.
115 Light intensities were measured using ILT 5000 research radiometer at 15 cm distance
116 below sea water level of the tank. The intensity of green LEDs at 20 lux, 35 lux, and
117 50 lux is 24 $\mu\text{W}\cdot\text{cm}^{-2}$, 54 $\mu\text{W}\cdot\text{cm}^{-2}$, 90 $\mu\text{W}\cdot\text{cm}^{-2}$, respectively. In the same order of
118 illumination level, the intensity for orange LEDs was 20 $\mu\text{W}\cdot\text{cm}^{-2}$, 21 $\mu\text{W}\cdot\text{cm}^{-2}$, and 24
119 $\mu\text{W}\cdot\text{cm}^{-2}$ while for the white LEDs was 15 $\mu\text{W}\cdot\text{cm}^{-2}$, 76 $\mu\text{W}\cdot\text{cm}^{-2}$, and 94 $\mu\text{W}\cdot\text{cm}^{-2}$.

120 The order of the experimental procedures is as follows. Firstly, before being
121 tested 30 scad were left at the experimental tank at least three days to acclimate, and
122 were subjected to a 12 L:12 D photoperiod (light from 06:00 to 18:00; dark from 18:00
123 to 06:00). Ambient illumination at 15 cm deep below seawater-level was about 16
124 $\text{nW}\cdot\text{cm}^{-2}$ in light conditions. All experimental sessions started at 19:00 and ended at
125 22:00. Secondly, before the experiment was started and between each experiment, fish
126 were kept in the dark state for 30 minutes to ensure their retina in a scotopic condition.
127 Subsequently, each lamp was turned on for 30 minutes to allow fish to respond and
128 adapt to the light. Visual observation and video recording using the infrared camera
129 were conducted during the dark and lighted conditions. Three replications were
130 conducted for each experiment (Marchesan *et al.* 2005). A total of 540 minutes of video
131 recording was analysed for each color to define fish proportion, scad swimming speed

132 around illumination zone, mean of nearest neighbour distance (MNND), and swimming
133 pattern of the fish schooling.

134

135 **Retinular Response to Irradiance Changes**

136 We used eighteen fish for the retinal adaptation experiment using the following
137 procedure. Firstly, two fish were taken from the storage tank and placed in a cylinder
138 tank with diameter 50 cm and height 43 cm. After 30 minutes set in the dark state, each
139 LED lamp was illuminated for approximately 30 min, and at the end of each treatment,
140 eye specimens from both fish were collected. Subsequently, each specimen was fixed in
141 Bouin's solution and infiltrated with paraffin. Tissue samples were cut in cross-sections
142 of 4-6 μm thickness and were stained with haematoxylin and eosin for examination
143 under the microscope. This histological process followed the procedures from Arimoto
144 *et al.* (2010) and Jeong *et al.* (2013).

145

146 **Fishing Experiment**

147 The result of laboratory experiment was applied to define the suitable LEDs color for
148 the fishing trial which was conducted using a fixed lift net in Banten Bay during peak
149 fishing season on August 2018. The fishing trial was conducted at 10 m water depth as
150 common fishing ground in Banten Bay. According to the laboratory experiment, scad
151 are especially responsive to white and green LEDs. Therefore, both lamps were
152 compared to a fluorescent lamp, the light source used in the existing lift net fishing. We
153 conducted the fishing experiment using 50 W of a fluorescent lamp (typical lamp for lift
154 net fishing) and 1.4 W of LEDs due to the similar light output in the seawater column
155 ($12\text{-}15 \mu\text{W}\cdot\text{cm}^{-2}$; measured using ILT 5000 at 1 m below sea water). Ten fish were
156 collected from each lamp making it 30 fish in total. Subsequently, all fish's eyes went

157 through the histological procedures, followed by the examination of reticular adaptation
158 under the microscope.

159

160 **Data Analysis**

161 In order to determine the degree of fish preference on each light stimulus, the proportion
162 of fish at each zone was analysed by counting the number of gathered fish in each zone
163 per minute observation (Kim and Mandrak 2017). Social behaviour was determined by
164 the mean nearest neighbour distance (MNND), which is the average of the planar
165 distances between each fish (head) and its closest neighbour (Parrish *et al.* 2002). It was
166 used to define the effect of different colors and intensity of schooling characteristics of
167 fish (Torisawa *et al.* 2007; Jolles *et al.* 2017). The MNND was analysed using images
168 that converted from the movie at the beginning (< 10 min), intermediate (11-20 min),
169 and the end of observation (21-30 min). The distance was analysed with Kinovea 0.8.15
170 at the center head of fish (Fig 2).

171 The degree of retinal light adaptation was represented in the adaptation ratio (%)
172 (Arimoto *et al.* 2010), which was calculated by $(B/A) \times 100$ (%), where A (μm)
173 represents the distance between the limiting membrane and the surface of the retina, and
174 B (μm) represents the migration of cone cells when it was stimulated by light. A and B
175 were measured using photomicrographs (Fig. 3). Swimming patterns at both LEDs
176 colors and irradiance levels were analysed by using video tracking and trajectory
177 software (Kinovea 0.8.15). Videotapes were preliminary observed at 4X speed, to
178 obtain the first qualitative swimming pattern and the characteristic of each stage. In all
179 experiments at every repetition, three dominant swimming patterns from each LED's
180 stimulus were chosen at the beginning, intermediate and the end of the observation
181 period. Parameters used to analyse the swimming speed of each pattern in total length

182 per second (TL/s) are (1) time-lapse in each pattern; (2) number of frames; (3) distance
183 of each pattern. One-way ANOVA was applied to analyse the effect of different light
184 stimuli (as explanatory variable) to proportion, MNND, and swimming speed during
185 observation (as response variable). Post-hoc comparisons, wherever significance was
186 found, were conducted using Tukey HSD test with the significance level was set at
187 $p < 0.05$.

188

189

190 **Results**

191 **Fish Preference to Light Stimuli**

192 The scad responded to the different light colors. At all illumination levels of each color,
193 fish showed high aggregation levels to the light zone. It was indicated by higher fish
194 proportions in zone 3 and 4 than dark zone as presented in Fig. 4. However, there was
195 not a significant difference in fish proportions at the dark condition for all zones (zone 1
196 to 6). The fish proportion at the dark condition between the range 14 and 19%. The
197 proportion tended to increase related to the aggregating of light intensity, especially at
198 the light zone. At the low intensity, the proportion of fish at zone 3 and zone 4 was
199 ranged between 22-32%. However, the proportion was increased to 34-44% at high
200 intensity level. There was also evidence to suggest that light intensity (in the range 15-
201 $94 \mu\text{W}\cdot\text{cm}^{-2}$) influences the behaviour of the fish by modifying swimming aggregations and
202 preference in all LEDs colors.

203

204

205

206

207

208 **Relationship Between The Retinular Response and Irradiance Change**

209 The light adaptation of scad was influenced by LEDs color and intensity. The degrees of
210 adaptation of scad at scotopic adaptation are in the range between 26 and 34%.
211 Adaptation ratio increased with increasing light intensity at each LEDs color (Fig. 5a).
212 The green LEDs generated the highest adaptation ratio with a slight increase, range 83%
213 (low intensity) to 93% (high intensity). However, the degree of light adaptation with
214 orange and white LEDs produced a various tendencies. The adaptation ratio of orange
215 LEDs at low intensities is 32%, and increase to 67% for the high light level.
216 Furthermore, white LEDs generated higher adaptation ratio than orange LEDs with the
217 ratio between 73% (low intensity) to 92% (high intensity).

218

219 **Swimming Behaviour**

220 The swimming behaviour of scad was strongly affected by light intensities at each LED
221 color. There was a significant decrease of MNND in all treatment with increasing
222 intensity. The farthest individual distance generated with orange LED was 14.8 cm,
223 while the closest distance was found at a white LED of 8.2 cm. In all experiments, the
224 decline of MNND has a relationship with increasing swimming speed. Scad has the
225 fastest swimming speed at green LED approximately $3.0 \text{ TL}\cdot\text{s}^{-1}$, while the lowest speed
226 was initiated at low intensity of white LED approximately $1.4 \text{ TL}\cdot\text{s}^{-1}$ (Fig. 6).

227 The different LED treatments also influenced the pattern of swimming
228 behaviour. In all dark conditions, fish swam randomly around the experiment tank.
229 There are inconsistent and irregular swimming patterns of scad during the dark
230 observation period. The light exposure caused changes in swimming behaviour. In low
231 intensity, the different color of LEDs did not affect the behavioural patterns. Moreover,
232 the increasing light intensity induces the transformed swimming pattern in all colors.

233 The fish swam randomly and inconsistently at a high intensity of the white LED.
234 However, the scad showed a consistent response to orange and green LED with
235 different radii in swimming patterns. Its radius with green LED is closer to the main
236 light zone than orange LEDs, as presented in Figure 7. Moreover, there were constant
237 and stable swimming patterns related to the time elapsed at the green LEDs,
238 approximately after 20 minutes of observation. The specifics of fish swimming
239 behaviour are presented in Table 1.

240

241 **Fishing Trials**

242 There are 1,082 scads were caught during fishing experiment. The light adaptation of
243 the retina collected during the fishing trial is shown in Fig 5b. The cone index was
244 found to be between the range of 78 and 91%. The green LED generated a higher mean
245 adaptation ratio (84%) than white LED (81%) and a fluorescent lamp (83%). However,
246 there were no significant differences in cone index from the sea experiment ($P>0.05$).

247

248 **Discussions**

249 The highest number of fish proportion in the bright observation zone indicated the scad
250 as a phototaxis fish that attracted by light. The proportion was superior to the bright
251 zones. However, these zones have a smaller area than shadow zones. There were
252 significant differences in the fish proportion between colors and intensities, whereas the
253 proportion in the bright zone at each color gradually increased with rising intensity. The
254 brightness level influences the level of fish activity. Thus, it would have been relevant
255 to increase the fish proportion in all bright zones (Marchesan *et al.* 2005; Utne-Palm *et*
256 *al.* 2018). This condition is an adaptation response to maintaining the formed

257 characteristic of scad schooling behaviour, related to the exposure of light intensity in
258 their environment (Woodhead 1966; Martin and Perez 2006).

259 There were significant differences in light adaptation ratio between dark and
260 light state ($p < 0.05$). The degree of light adaptation ratio has a positive association with
261 an increase of light intensity (Susanto *et al.* 2017c). With all colors used in the
262 experiment, the adaptation stage of cone cells increases with expanding intensity. The
263 exposure of high-intensity LEDs induces the cone cells into photopic adaptation rapidly.
264 Thus the light adaptation ratio was increased (Tamura and Niwa 1967; Nakano *et al.*
265 2006; Migaud *et al.* 2007). The green LEDs generated the highest adaptation ratio of
266 scad in all intensity levels. Thus, it would have been relevant to conclude that the
267 maximum sensitivity of the Carangidae fish family, including scad, has peak sensitivity
268 between 494-500 nm (Munz and McFarland 1973).

269 Light intensity has prevailing influence on the visual ability of fish. However,
270 scad's ability to use vision to maintain the schooling characteristic during light level
271 increases necessitates phototaxis. Moreover, there were significant differences in
272 swimming behaviour, including swimming patterns and MNND in the different light
273 conditions, whereas the fish activity increased with rising intensity. The MNND has a
274 negative relationship with light intensity, whereas the MNND decreased with increasing
275 intensity levels. However, the swimming speeds of scad showed different tendencies
276 with MNND during expanding light levels. The fish swam faster at the high intensity at
277 all LED colors. The high intensity induced fish easier to maintain the direction and
278 orientation of their schooling, due to an increase in their swimming speed at all
279 treatments (Miyazaki *et al.* 2000). Similar tendencies were found at the swimming
280 speed of Atlantic salmon *Salmo salar*. Its speed was increased from 0.2 BL/s to 0.5

281 BL/s related to the increase of the light level at sea cage observation (Hansen *et al.*
282 2017).

283 The swimming patterns of scad in the green and orange LEDs have similar
284 tendencies. However, the swimming radius at the green LED was closer to the center of
285 the light zone than an orange LED. It was related to the visual adaptation level and the
286 spectral sensitivity of scad. The scad have more reactive to the green light because it is
287 suitable with peak sensitivity level. The fish have a proper response to green light due to
288 an increase in visual ability and significant influence to fish capability to maintain their
289 schooling characteristics. Exposure of green light in different light intensities was
290 induced the stable and consistence swimming pattern. In one example of schooling
291 during increased light intensity, increasing visual ability influenced each individual,
292 enabling them to maintain their distance and formation relative to the rest of the school
293 during swimming (Glass *et al.* 1986; McMahon and Holanov 1995; Miyazaki and
294 Nakamura 1990).

295 Even though the orange light has longer wavelength than green light, it has
296 lower of photon energy. It cause the scads have less reactive and induce wider
297 swimming radius than green light. However, the swimming pattern of scad in orange
298 light was relatively stable and consistence during observation. In other example, orange
299 light has similar influenced with green light to the schooling characteristic of *Mugil*
300 *cephalus*, *Sparus auratus*, and *Lithognathus mormyrus* (Marchesan *et al.* 2005).

301 The light adaptation of scad from the fishing experiment has similar tendencies
302 with laboratory observations. The green LED generated a higher degree of adaptation
303 than the white LED and fluorescent lamp at the same intensity. The information on the
304 retinular response and adaptation to light source was utilized in studying the

305 relationship between a light fishing procedure, light color, and light intensity to develop
306 an efficient use of the LED fishing lamp (Jeong *et al.* 2013). In this research, we
307 compare the characteristics of scad swimming behaviour, and light adaptation between
308 experimental tanks and fishing trials to determine the suitable low powered LED color
309 as a light source when fishing. From these results, the green LED, which induces good
310 light adaptation and stable swimming patterns, is suitable enough to substitute
311 fluorescent lamps currently used in lift net fishing.

312 The combination in both green and white LED can be a more effective light
313 attractant to scad fishing at lift net fisheries. In lift net fisheries, white LED is useful
314 when gathering scads and other target species at the initial fishing operation. However,
315 the swimming pattern of fish school at white LED was random and unstable, due to the
316 light source having to change with green LED when focusing the fish at a catchable
317 area. Green light would be more suitable to keep fish close to the light source.
318 Moreover, this light not induces stress behaviour for long exposure time (Shin *et al.*
319 2013; Stien *et al.* 2014; Sierra-Flores *et al.* 2015). The application of green light in
320 focusing of fish can reduce uncaught fish during hauling process and improve the
321 fishing efficiency and effectiveness in lift net fishing.

322 The LED innovation as artificial light has several advantages. The LED provides
323 maximum illumination power, combined with minimum energy consumption, long
324 lifespan, high efficiency, better chromatic performance, and reduced environmental
325 impact compared to traditional lighting technology (Matsushita *et al.* 2012; Matsushita
326 and Yamashita 2012; Yamashita *et al.* 2012; Breen and Lerner 2013; Hua and Xing
327 2013; Yeh *et al.* 2014; Nguyen and Tran 2015; An *et al.* 2017). However, further

328 fishing trials are recommended to validate the effectiveness of both white and green
329 LED as a light stimulus for gathering and focusing scad at lift net fisheries.

330

331

332 **Conclusions**

333 Present investigation showed the white LED is a suitable enough to attract fish to
334 catchable area while the green LED is an effective color for focusing and control
335 behaviour of scad in catchable area. We conclude that combination of white and green
336 LED can be a more effective light attractant to scad fishing at lift net fisheries.

337

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343 **References**

- 344 An YI, P He, T Arimoto, UJ Jang (2017). Catch performance and fuel consumption of
345 LED fishing lamps in the Korea hairtail angling fishery. *Fish Sci* 83:343–352
- 346 Arimoto T, CW Glass, X Zhang (2010). *Fish vision and its role in fish capture*. He, P.
347 (Eds), *Behaviour of marine fishes: capture processes and conservation*
348 *challenges*. Blackwell Scientific, USA
- 349 Ben-Yami M (1976). *Fishing with light*. Fishing News Books, Oxford USA
- 350 Breen M, A Lerner (2013). An introduction to light and its measurement when
351 investigating fish behaviour. Symposium on the Light session and the Topic
352 Group Lights: ICES-FAO Working Group on Fishing Technology and Fish
353 Behaviour. May 6–10, Bangkok, Thailand

354 Chaa BJ, BS Baea, SK Chob, JK Oh (2011). A simple method to quantify fish
355 behaviour by forming time-lapse images. *Aquacultural Engineering* 51:15-20

356 Glass CW, CS Vardle, WR Mojsiewicz (1986). A light intensity threshold for schooling
357 in the Atlantic Mackerel *Scomber scombrus*. *J Fish Biol* 29(Suppl A):71-81

358 Guntur, Fuad, A Munataha (2015). Effect of underwater lamp intensity on the lift net's
359 fishing catches. *Mar Fish* 6(2):195-202

360 Hansen TJ, PG Fjellidal, O Folkedal, T Vågseth, F Oppedal (2017). Effects of light
361 source and intensity on sexual maturation, growth and swimming behaviour of
362 Atlantic Salmon in sea cages. *Aquac Environ Interact* 9:193-204

363 Hua LT, J Xing (2013). Research on LED fishing light. *Res J Appl Sc, Eng and Technol*
364 5:4138-4141

365 Jeong H, S Yoo, J Lee, YI An (2013). The reticular responses of common squid
366 *Todarodes pacificus* for energy efficient fishing lamp using LED. *Renew Energy*
367 54:101-104

368 Jolles JW, NJ Boogert, VH Sridhar, LD Couzin, A Manica (2017). Consistent
369 individual differences drive collective behaviour and group functioning of
370 schooling fish. *Current Biol* 27: 1-7

371 Kim J, NE Mandrak (2017). Effects of strobe lights on the behaviour of fresh water
372 fishes. *Environ Biol Fish* 100:1427-1434

373 Marchesan M, M Spoto, L Verginellab, EA Ferreroa (2005). Behavioural effects of
374 artificial light on fish species of commercial interest. *Fish Res* 73:171-185

375 Martin RS, JAA Perez (2006). Cephalopods and fish attracted by night lights in coastal
376 shallow-waters, off Southern Brazil, with the description of squid and fish
377 behaviour. *Revista de Etologia* 8:27-34

378 Matsui H, G Takayama, Y Sakurai (2016). Physiological response of the eye to
379 different colored light-emitting diodes in Japanese flying squid *Todarodes*
380 *pacificus*. *Fish Sci* 82:303-309

381 Matsushita Y, T Azuno, Y Yamashita (2012). Fuel reduction in coastal squid jigging
382 boats equipped with various combinations of conventional metal halide lamps and
383 low-energy LED panels. *Fish Res* 125-126:14-19

384 Matsushita Y, Y Yamashita (2012). Effect of a stepwise lighting method termed “stage
385 reduced lighting” using LED and metal halide fishing lamps in the Japanese
386 common squid jigging fishery. *Fish Sci* 78:977-983

387 McMahon TE, SH Holanov (1995). Foraging success of largemouth bass at different
388 light intensities: implications for time and depth of feeding. *J Fish Biol* 46:759-
389 767

390 Migaud H, M Cowan, J Taylor, HW Ferguson (2007). The effect of spectral
391 composition and light intensity on melatonin, stress and retinal damage in post-
392 smolt Atlantic salmon, *Salmo salar*. *Aquac* 270:390-404

393 Miyazaki T, Y Nakamura (1990). Single line acuity of 0-yearold Japanese parrotfish
394 determined by the conditioned reflex method. *Nippon Suisan Gakkaishi* 56:887-
395 892

396 Miyazaki T, S Shiozawa, T Kogane, R Masuda, K Maruyama, K Tsukamoto (2000).
397 Developmental changes of the light intensity threshold for school formation in the
398 striped jack *Pseudocaranx dentex*. *Mar Ecol Prog Ser* 192:267-275

399 Ministry of Marine Affairs and Fisheries Republic of Indonesia (2018). *Statistics of*
400 *Fish Production based on Fishing Gear in Indonesia 2017*. Jakarta, Indonesia.

448 Torisawa S, T Takagi, H Fukuda, Y Ishibashi, Y Sawada, T Okada, S Miyashita, K
449 Suzuki, T Yamane (2007). Schooling behaviour and retinomotor response of
450 juvenile Pacific bluefin tuna *Thunnus orientalis* under different light intensities. *J*
451 *of Fish Biol* 71:411-420

452 Utne-Palm AC, M Breen, S Løkkeborg, OB Humborstad (2018). Behavioural responses
453 of krill and cod to artificial light in laboratory experiments. *Plos One* 13:1-17

454 Viscido SV, D Grünbaum (2002). Self-organized fish schools: an examination of
455 emergent properties. *Biol Bull* 202:296–305

456 Wang JH, S Fisler, Y Swimmer (2010). Developing visual deterrents to reduce sea
457 turtle bycatch in gill net fisheries. *Mar Ecol Progr Ser* 408:241–250

458 Woodhead PMJ (1966). The behaviour of fish in relation to light in the sea. *Oceanog*
459 *and Marine Biol Annu Rev* 4:337-403

460 Yamashita Y, Y Matsushita, T Azuno (2012). Catch performance of coastal squid
461 jigging boats using LED Panels in combination with metal halide lamps. *Fish Res*
462 113: 182–189

463 Yeh N, P Yeh, N Shih, O Byadgi, TC Cheng (2014). Applications of light-emitting
464 diodes in researches conducted in aquatic environment. *Renew Sustain Energy*
465 *Rev* 32:611–618

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467
468
469
470
471
472

401 Munz FW, WN McFarland (1973). The significance of spectral position in the
402 rhodopsins of tropical marine fishes. *Vis Res* 13:1829-1874

403 Nakano N, R Kawabe, N Yamashita, T Hiraishi, K Yamamoto, K Nashimoto (2006).
404 Color vision, spectral sensitivity, accommodation, and visual acuity in juvenile
405 masu salmon *Oncorhynchus masou masou*. *Fish Sci* 72:239-249

406 Nguyen QK, DP Tran (2015). Benefits of using LED light for purse seine fisheries: A
407 case study in Ninh Thuan Province, Viet Nam. *Fish People* 13:30-36

408 Nguyen KQ, PD Winger, C Morris, SM Grant (2017). Artificial lights improve the
409 catchability of snow crab (*Chionoecetes opilio*) traps. *Aquac Fish* 2:124–133

410 Nguyen KQ, PD Winger (2019). Artificial light in commercial industrialized fishing
411 applications: a review. *Rev in Fish Sci & Aquac* 27:106-126

412 Ortiz N, JC Mangel, J Wang, J Alfaro-Shigueto, S Pingo, A Jimenez, T Suarez, Y
413 Swimmer, F Carvalho, BJ Godley (2016). Reducing green turtle bycatch in small-
414 scale fisheries using illuminated gillnets: The cost of saving a sea turtle. *Mar Ecol*
415 *Progr Ser* 545:251–259

416 Parrish JK, SV Viscido, D Grunbaum (2002). Self-organized fish schools: an
417 examination of emergent properties. *Biol Bull* 202:296–305

418 Pignatelli V, SE Temple, T-H Chiou, NW Roberts, SP Collin, NJ Marshall (2011).
419 Behavioural relevance of polarization sensitivity as a target detection mechanism
420 in cephalopods and fishes. *Phil Trans R Soc B* 366:734-741

421 Rudin MJ, R Irnawati, A Rahmawati (2017). Differences of fixed lift net catch result by
422 using CFL lamps and underwater Led in Banten Bay water. *Mar and Fish Journal*
423 7(2):167-180

424

425 Shin SH, NN Kima, YJ Choi, HR Habibi, JW Kim, CY Choi (2013). Light-emitting
426 diode spectral sensitivity relationship with reproductive parameters and ovarian
427 maturation in Yellowtail damselfish, *Chrysiptera parasema*. *Journal of*
428 *Photochem and Photobiol B: Biology* 127:108-113

429 Sierra-Flores R, A Davie, B Grant, S Carboni, T Attack, H Migaud (2015). Effects of
430 light spectrum and tank background colour on Atlantic cod (*Gadus morhua*) and
431 turbot (*Scophthalmus maximus*) larvae performances. *Aquac* 450:6-13

432 Solomon OO, OO Ahmed (2016). Fishing with light: Ecological consequences for
433 coastal habitats. *Int J Fish Aquac Stud* 4:474–483

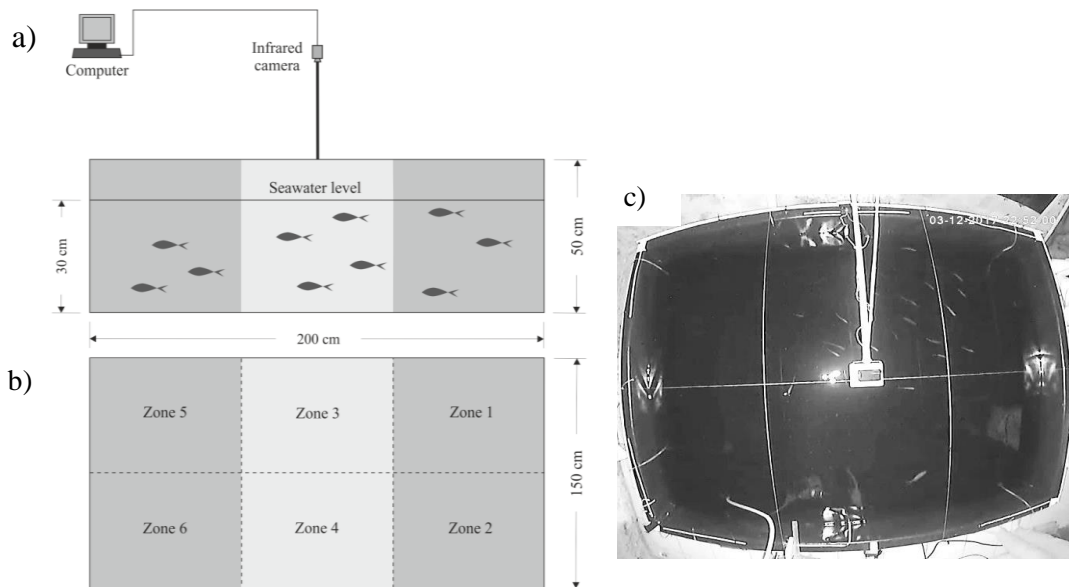
434 Stien LH, JE Fosseidengen, ME Malm, H Sveier, T Torgersen, DW Wright, F Oppedal
435 (2014). Low intensity light of different colours modifies Atlantic salmon depth
436 use. *Aquac Engine* 62:42-48

437 Susanto A, R Irnawati, Mustahal, MA Syabana (2017a). Fishing efficiency of LED
438 lamps for fixed lift net fisheries in Banten Bay Indonesia. *Turkish J of Fish and*
439 *Aqua Sci* 17:283-291

440 Susanto A, MS Baskoro, SH Wisudo, M Riyanto, F Purwangka (2017b). Seawater
441 battery with Al-Cu, Zn-Cu, Gal-Cu electrodes for fishing lamp. *Inter J of Renew*
442 *Energy Res* 7:1857-1868

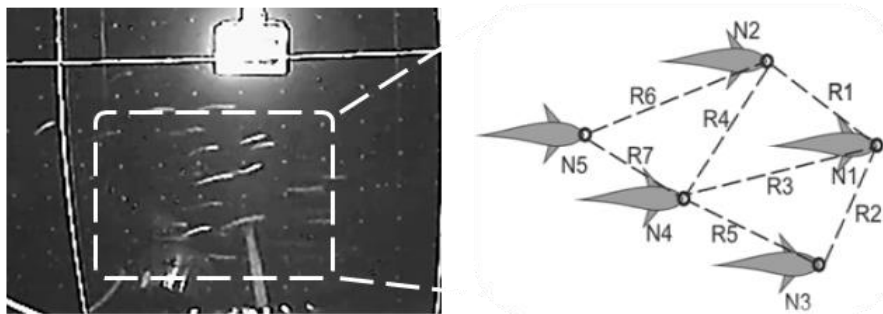
443 Susanto A, ADP Fitri, Y Putra, H Sutanto, T Alawiyah (2017c). Response and
444 adaptation of Anchovy (*Stolephorus* sp.) to light emitting diode (LED) lamp. *Mar*
445 *Fish* 8:39-49

446 Tamura T, H Niwa (1967). Spectral sensitivity and color vision of fish as indicated by
447 S-potential. *Comp Biochem Physiol* 22:745-754



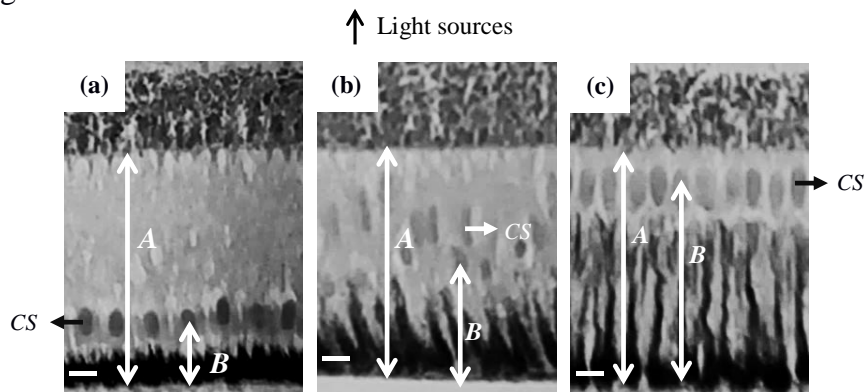
473

474 **Fig. 1:** The open tank experiment for the behavioural response. The side view of
 475 experimental tank set up (a), top view (b), and infrared camera view (c).



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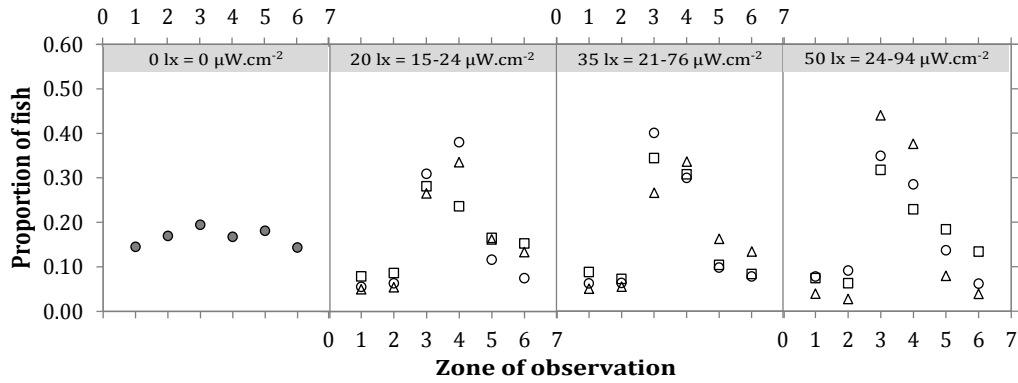
477 **Fig. 2:** Illustration of NND method from the image recording. N1 to N5 represent the
 478 number of fish. R1 to R7 represent the planar distances between each fish (head) and its
 479 closest neighbor



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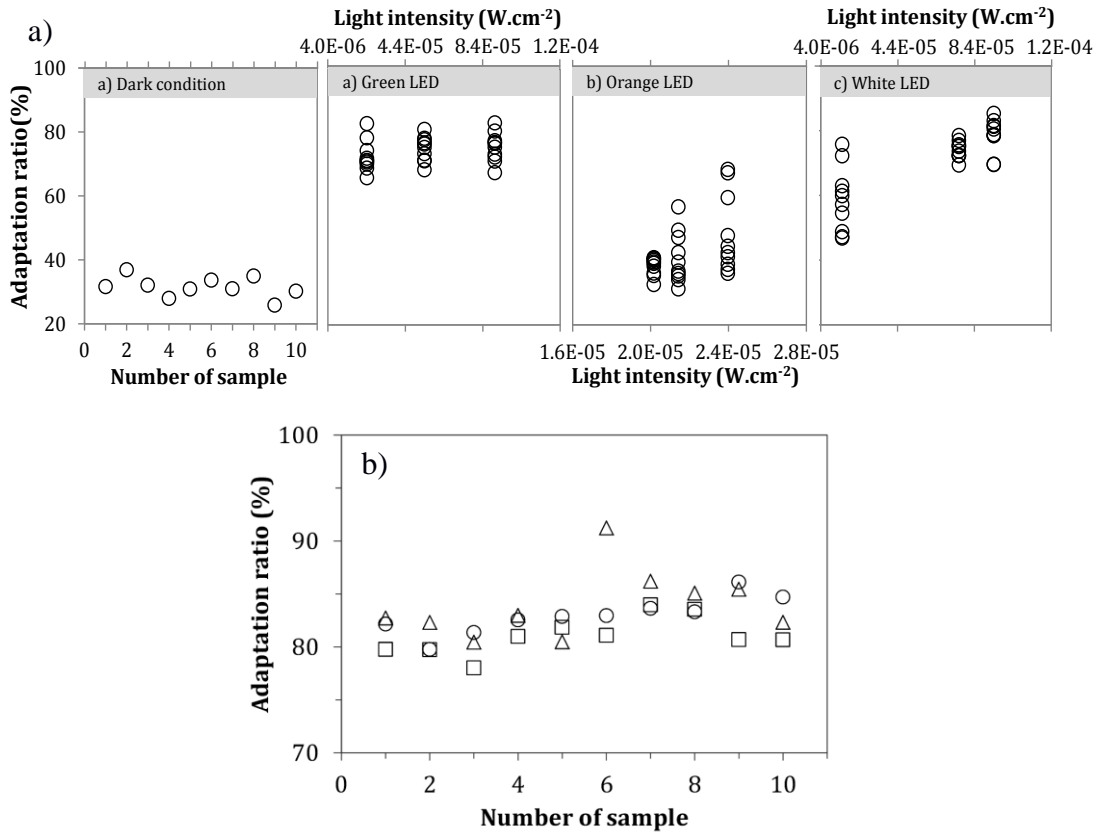
481 **Fig. 3:** Photomicrographs show various states of retinal light adaptation of *Selaroides*
 482 sp. A thickness from the limiting membrane to the surface of the retina and B thickness
 483 of cone cell migration. **a.** Dark adapted, **b.** transitional stage, and **c.** light adapted. CS:
 484 cone cell. Scale bar = 10 μ m.

485



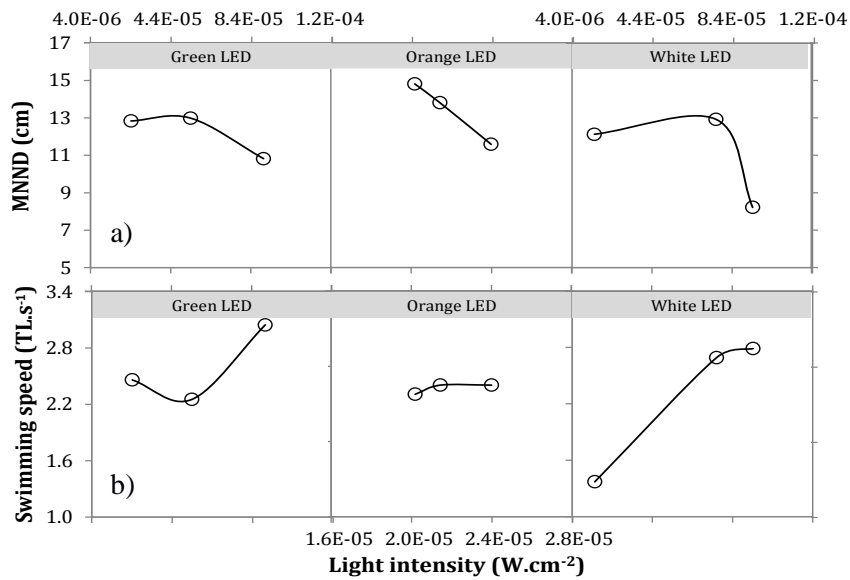
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487 **Fig. 4:** The proportion of fish related to the color and light intensity. The proportion of
 488 scad observed during replicated color treatments (green-circle; orange-square; white-
 489 triangle;) and dark condition (filled circle).
 490



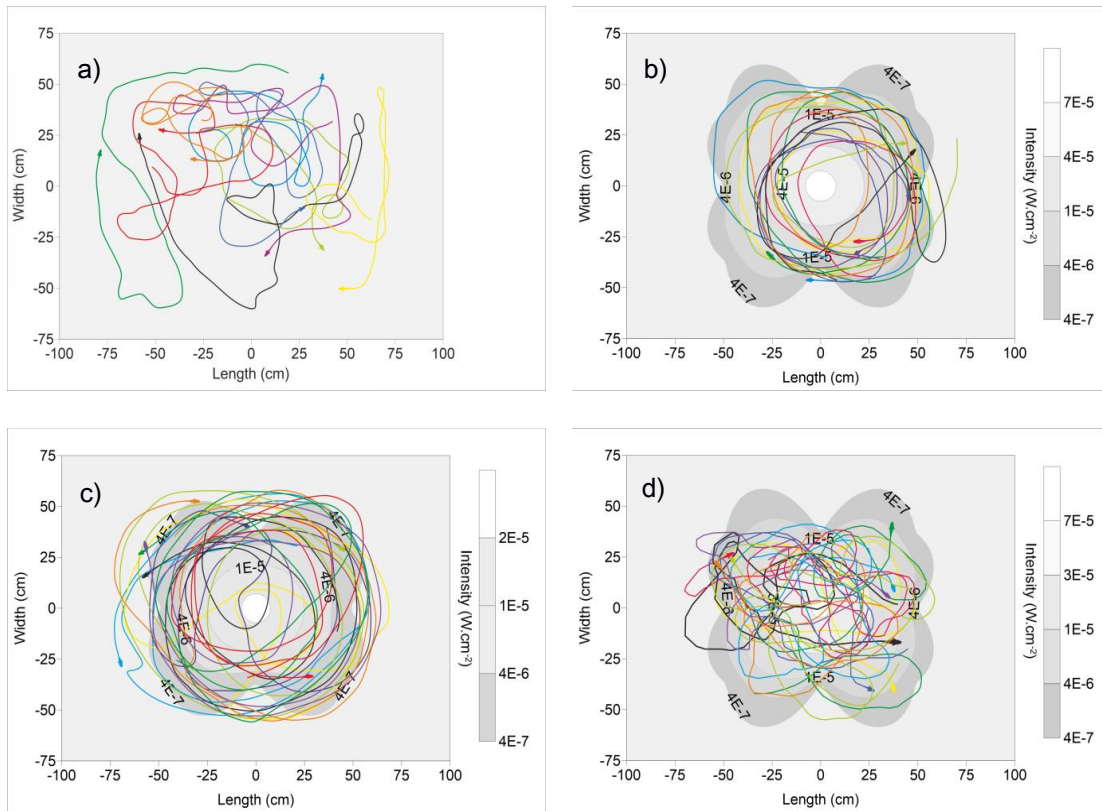
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492 **Fig. 5:** The light adaptation of scad retina cells to different color and light intensity in
 493 laboratory experiment (a) and the light adaptation of the retina cells collected from the
 494 fishing experiment (b). The cone index of fluorescent-circle, white LED-square, and
 495 green LED-triangle.



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Fig. 6: The swimming behaviour of scad to different LED colors and intensities. The mean nearest neighbor distances (a) and swimming speed (b).



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Fig.7: The individual swimming pattern of scad in different color and LEDs intensity. The swimming pattern in dark condition (a), green LED (b), orange LED (c) white LED (d). Different fish are color-coded.

506 **Table 1:** Fish behaviour related to the time elapsed observation

Time elapsed (minute)	Fish Behavioural Response
0 - 5	There was no schooling and swimming behaviour pattern at the beginning treatment. Fish swam in all directions due to orientation and adaptation period related to the light color and intensity at the experimental tank.
6 - 10	The fish started to school with several swimming patterns. However, there were an unstable direction and swimming speed.
11 - 20	There was a stable and consistent swimming pattern. The swimming speed was increased related to time-lapse.
21 - 30	The swimming patterns were stable and consistent with steady swimming speed. The radius of swimming was stable and relatively closest to the center of the light zone.

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