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Response of squids to colours and intensities of artificial light

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Abstract. A study on the response of big fin reef squid (*Sepioteuthis lessoniana*) and mitre squid (*Loligo chinensis*) to different characteristics of artificial light was conducted in an experimental cage. The response of squids to lights was determined by the Average Mean Displacement Position. The two species responded significantly differently to intensities but not to colours of the light. *Sepioteuthis lessoniana* preferred a range of underwater illuminance of 1.5-25.0 lux whereas *Loligo chinensis* preferred a range of 1.5 - 22.5 lux. However, a peak range for both species was recorded at 2.5 - 10.0 lux. *Sepioteuthis lessoniana* showed a stronger positive phototactic behavior than *Loligo chinensis*. This study provides the knowledge on the behavioral response of squid to artificial light, and it may be useful to multi-species and species-selective harvesting techniques.

Abstrak. Satu kajian mengenai tindakbalas sotong mabang (*Sepioteuthis lessoniana*) dan sotong torok (*Loligo chinensis*) terhadap ciri cahaya tiruan berlainan telah dijalankan di dalam sangkar ujian. Tindakbalas sotong ini ditentukan melalui Purata Min Kedudukan Sesaran. Kedua-dua spesies sotong memberi tindakbalas berbeza dengan signifikan terhadap intensiti cahaya berlainan tetapi tidak kepada warna cahaya berlainan. *Sepioteuthis lessoniana* memilih julat keamatan cahaya bawah air 1.5 - 25.0 manakala *Loligo chinensis* memilih 1.5 - 22.5. Namun begitu, kedua-dua spesies mencatatkan julat puncak 2.5-10.0. *Sepioteuthis lessoniana* menunjukkan perangai fototaktic positif yang lebih kuat berbanding *Loligo chinensis*. Kajian ini memberi pengetahuan mengenai perangai tindakbalas sotong terhadap cahaya tiruan, dan boleh memungkinkan teknik penangkapan secara multispesies dan spesies-selektif dijalankan.

Introduction

Phototactic behavior, *i.e.*, the attraction to artificial light, has been observed both in fish and squids. Some pelagic fish species and squids are known to have a positive phototaxis as they move towards artificial light and aggregate in the illuminated zone [1-6]. This peculiar behaviour has been exploited by the fishing industry.

A knowledge on the response of squid to different characteristics of artificial light is indispensable in improving its catching efficiency. Squid fishermen in Malaysia use lights of different colours and intensities in the belief that these are of different levels of attraction to squids. Ogura [7] reported that the species respond to light of intensities of up to 10 lux, but the squids tend to disperse under excessively strong light. Nomura [8] conducted an experiment on Japanese squid (*Todarodes pacificus*) and found that the appropriate luminosity for attracting the species was 0.2 to 2.0 lux. Research has not been conducted on other species of squids that are found in abundance in tropical waters. The study examines the behaviour of tropical squids in their response to artificial light.

Experimental

The study was conducted in the sheltered sea of Kapas Island off the coast of Terengganu, Peninsular Malaysia (5°13.6' N latitude, 103° 15.8' E), at a depth of approximately 5 m. A

15.8' E), at a depth of approximately 5 m. A cage was constructed from chengal wood (*Balanocarpus heimii*); the frame was 3.67 x 3.05 x 1.83 m. The frame was lined with nylon netting of 2.7 m mesh size. For observational purposes, the net cage was divided into three equal quadrants (1.22 m each) in the horizontal direction and three equal quadrants in the vertical direction (*i.e.*, 9 equal quadrants). The cage was supported by a floating frame that was strong enough to be used as a platform (Figure 1).

Live squids captured by using scoop nets in waters near the study location to minimise problems associated with handling and transportation. The species of squid were the bigfin reef squid *Loligo chinensis* and mitre squid *Sepioteuthis lessoniana*. Fifteen strong and healthy squids from each species were collected and immediately placed inside the cage. The squids were kept for three days for full recovery from handling by feeding them with fresh fish before conducting experiments.

The lighting equipment comprised a 2.2 HP electrical generator, four 150-watt bulbs (blue, red, white and yellow), and four incandescent (white) 150, 300, 450 and 600 watt bulbs. The light source was set at 30 cm above the sea level. The generator that supported the lighting system was placed in a dory at approximately 15 m from the cage to minimise the effect of noise on squid behaviour.

Data on underwater illumination and behaviour of the squid were recorded throughout the study. The underwater illumination for the light sources was measured at the centre of each quadrant by using a Quantum Radiometer Photometer (LI-COR, LI-189) and an underwater sensor (UWQ 5015). The approximate conversion factor of the meter is 1,000 lux = 20 μmol $s^{-1}m^{-2}$.

Two observers were used so as to minimise observational bias. The response of the squids in terms of as direction of movement, position after a period of time and other behaviour were visually noted and recorded at the 0^{th} (when the light was switched on), 5^{th} and 10^{th} minute. The Average Mean Displacement Position (AAMDP) of the squids in response to the lights was calculated according to Nestler *et al.* [9]. The distances from the centre of the quadrant to the end of the net nearest to the light source were also calculated (Table 1). The displacement position of the squids was measured according to the quadrant of they were present in. Where the squids were present in more than one quadrant, the average distance of the squids was calculated by multiplying the number of squids in each quadrant with the quadrant distance and dividing by the number of squids. Lines of isoilluminance for all degrees of intensities were determined and these lines were coordinated with the positions of squids to determine the preferred and maximum range of illumination.

Table 1. Underwater illuminance (lux) at the centre of quadrants at different intensities (watts) of light

Quadrant	Distance* (m)	150 w	300 w	450 w	600 w
A1	0.76	54.35	78.50	178.55	233.75
A2	1.50	14.30	32.70	78.60	127.25
A3	2.37	8.25	19.50	36.50	58.70
B1	1.89	1.00	1.95	2.40	2.25
B2	2.29	3.95	5.50	9.75	14.70
B3	2.93	1.00	3.50	6.16	13.05
C1	3.08	0	0.50	0.75	0.85
C2	3.34	0	1.50	1.65	6.60
C3	3.81	0	1.50	1.50	3.55

*Calculated distance from the end of the net nearest the light source to the centre of each quadrant.

Table 2. AMDP of *S. lessoniana* and *L. chinensis* at various time and intensities of light

	S. Lessoniana			*L. chinensis*		
Intensity (watts)	0 min	5th min	10th min	0 min	5th min	10th min
150	2.72	1.76	1.80	3.22	2.39	2.43
300	2.88	1.98	2.01	2.94	2.64	2.64
450	2.84	2.31	2.36	2.82	2.68	2.68
600	2.97	2.66	2.65	2.89	3.20	2.96
Mean	2.85	2.18	2.21	2.97	2.73	2.68

Table 3. AMDP of *S. lessoniana* and *L. chinensis* at various times and colours of light

	S. Lessoniana			*L. chinensis*		
Intensity (watts)	0 min	5th min	10th min	0 min	5th min	10th min
Red	2.97	2.13	2.17	2.95	2.51	2.54
Blue	2.70	2.13	2.04	3.03	2.62	2.55
Yellow	3.00	2.22	2.33	3.10	2.87	2.88
White	2.73	2.23	2.33	2.80	2.92	2.80

Table 4. Range of underwater illuminance and the number of squids at various intensities of light

Species	Intensity (watts)	Range of underwater illuminance (lux)			
		0-1.5	1.5-2.5	2.5- 0.0	10.0-22.
S. lessoniana	150	-	1.00±0.063	13.83±0.75	0.17±0.41
		-	0.83±0.75	13.83±0.75	0.33±0.52
		-	0.67±0.82	13.83±1.17	0.50±0.84
			0.17+0.41	14.75+0.75	0.67±0.55
L. chinensis	150	-	0.83±0.75	14.00±0.63	0.17±0.41
	300	-	0.67±0.82	14.00±0.63	0.33±0.52
	450	-	0.83±0.41	13.83±0.75	0.33±0.52
	600	-	0.50±0.55	14.17±0.75	0.33±0.52

Mean ±S.D. (n = 6).

Results and Discussion

Data of underwater illuminance for four levels of intensities of light are shown in Table 1. Data on the response of *Sepioteuthis lessoniana* and *Loligo chinensis* to the intensities and colours of light for each period of time are summarised in Table 2 and Table 3, respectively. The analysis of variance on the relation between the AMDP of both species for four intensities of

light sources (Table 2) did not show any significant difference at 0 minute ($P > 0.05$) but it was significantly different at the 5^{th} and 10^{th} minute ($P < 0.05$). Regression analysis carried out on the 5^{th} and 10^{th} minutes revealed a positive correlation between the AMDP of the squid and the intensities of light source. The AMDP increased with increasing intensity. However, the analysis of variance on the relation between the AMDP for four colours (Table 3) did not show any significant difference at the 0^{th}, 5^{th} and 10^{th} minutes ($P > 0.05$).

The relationship between underwater illumination and the number of squids is given in Table 4. The preferred range for *Sepioteuthis lessoniana* was 1.5 - 25.0 lux with the maximum at 2.5 - 10.0 lux. *Loligo chinensis* recorded a preferred range of 1.5 - 22.5 lux and a maximum of 2.5 - 10.0 lux.

The results suggest that *Sepioteuthis lessoniana* and *Loligo chinensis* are creatures that are easily attracted by artificial light. The response of the squids to light is a consequence of direct stimulus behaviour as the squids immediately lost the direction of movement when the light was switched on. A similar behavior is also reported for some fish species. Sasaki [10] reported that a school of horse mackerel is attracted initially by light without taking any prey. The same behaviour is also described in a report by Verheijen [11] on the systematic responses of fish to artificial light. The author noted that the self controlling system in the nerve centre of the fish acted naturally as the fish could select the appropriate degree of light intensity under natural light conditions. Under artificial lighting, however, this self controlling system is perturbed and the fish lose their sense of direction; the are easily attracted by artificial light through compulsory phototaxis.

According to a theory of optimum light for aquatic animals [12], each species has its own preferred range of underwater illumination. Results from this study show that *Sepioteuthis lessoniana* and *Loligo chinensis* prefer a level of 1.5 - 25.0 lux, with maximum of 2.5 - 10.0 lux. This is in agreement with a report by Ogura *et al.* [13] that revealed that the proper illumination for attracting the Japanese squid (*Todarodes pacificus*) is approximately 10 lux. As a comparison, other marine species such as anchovy, pacific saury and mackerel prefer 0.03 - 6.00 lux, 0.00 - 10.00 lux and 2.40 - 39.50 lux, respectively [12]. As squids seem to prefer underwater light illuminance similar to that of the Pacific saury, the behaviour could be manipulated for an economical multispecies harvesting.

Although both species of squids prefer an almost identical level of underwater illumination, their AMDP differ. Table 2 shows that the mean AMDP of *Sepioteuthis lessoniana* for all time intervals are smaller than the mean for *Loligo chinensis*, which means that *Sepioteuthis lessoniana* prefers to stay at a shorter distance than *Loligo chinensis* when responding to the same light intensity, *i.e.*, *Sepioteuthis lessoniana* has a stronger positive phototactic behaviour than *Loligo chinensis*. This observation is of use for species-selective harvesting.

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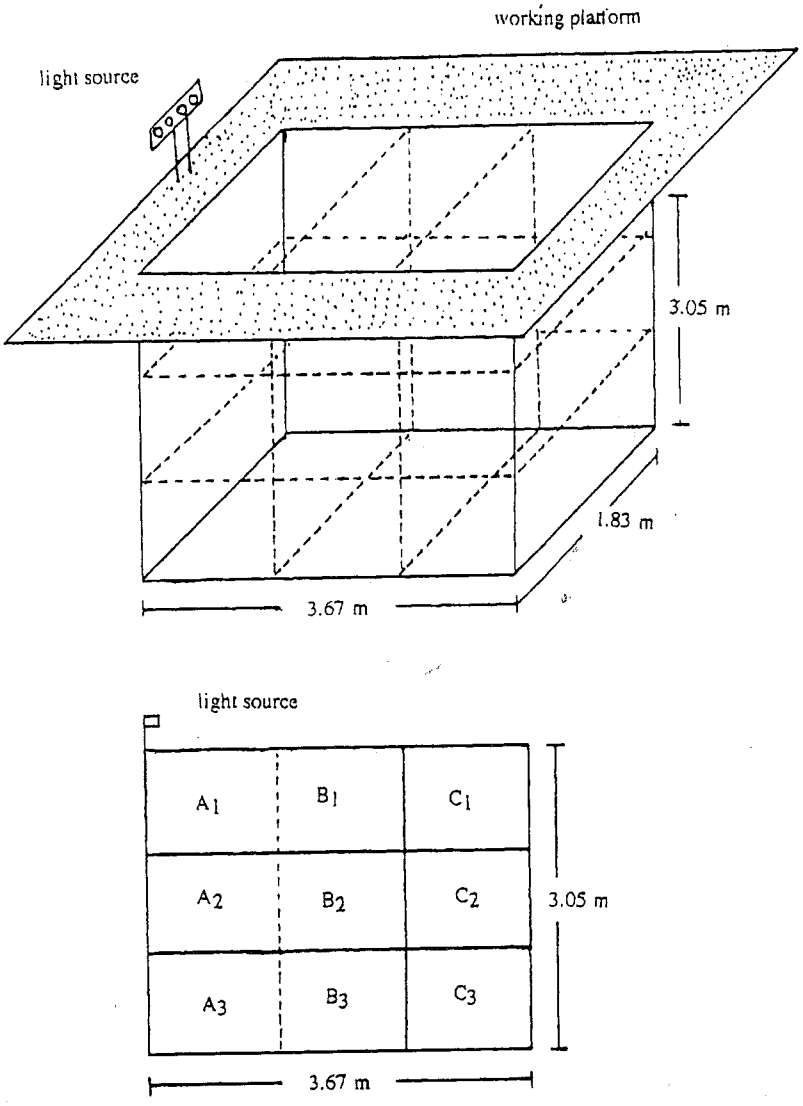

Figure 1. Configuration of the experimental cage.