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Response of Squids to Different Colours and Intensities of Artificial Light

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ABSTRAK

Satu kajian mengenai tindakbalas sotong mabang (Sepioteuthis lessoniana) dan sotong torok (Loligo chinensis) terhadap ciri berlainan cahaya tiruan telah dijalankan di dalam sangkar ujian. Tindakbalas sotong ini ditentukan melalui Purata Min Kedudukan Sesaran (AMDP). 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 lux manakala Loligo chinensis memilih 1.5-22.5 lux. Namun begitu, kedua-dua spesis mencatatkan julat puncak 2.5-10.0 lux. Sepioteuthis lessoniana mempunyai perangai fototaktic positif yang lebih kuat berbanding Loligo chinensis. Kajian ini memberi pengetahuan mengenai perangai tindakbalas sotong terhadap cahaya tiruan dan memungkinkan teknik penangkapan secara multispesis dan spesis-selektif dijalankan.

ABSTRACT

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 its Average Mean Displacement Position (AMDP). The two species responded significantly different to different intensities of light but not to different colours of the light. Sepioteuthis lessoniana preferred a range of underwater illuminance of 1.5-25.0 lux while Loligo chinensis preferred a range of 1.5-22.5 lux, but peak range for both species was recorded at 2.5-10.0 lux. Sepioteuthis lessoniana has a stronger positive phototactic behaviour than Loligo chinensis. This study provides the knowledge on the behavioural response of squid to artificial light and may pave a way for multi-species as well as species-selective harvesting techniques.

INTRODUCTION

Phototactic behaviour (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 by moving towards and aggregate in the illuminated zone of artificial lights (Ben-Yami 1976; Hayase *et al.* 1983; Imamura 1968; Maeda 1955; Matsunaga 1986; Nomura and Yamazaki 1977). This peculiar behaviour has been manipulated by many fisheries for successful harvesting operations.

Knowledge on the response of squid to different characteristics of artificial light is indispensable for improving catching efficiency. Squid fishermen in Malaysia use attracting lights of different colours and intensities with the belief that this causes different levels of attraction to squids. Ogura (1982) reported that the species respond to light having intensities of up to 10 lux but tend to disperse under excessive power of light. Nomura (1985) conducted an experiment on Japanese squid (*Todarodes pacificus*) and found that a proper luminosity to attract the species was between 0.2 to 2.0 lux. However, no research has been conducted on other species of squids that are found in abundance in tropical waters. The objective of the study was to determine the behaviour of tropical species of squids in response to the different characteristics of artificial light.

MATERIALS AND METHODS

The study was conducted during moonless nights (before and after the new moon) in sheltered waters of Kapas Island off the coast of Terengganu, Peninsular Malaysia at Latitude 5° 13.6'N and Longitude 103° 15.8'E with depth of water of approximately 5.0 m. An experimental cage was constructed from chengal wood (*Balanocarpus heimii*) with the frame having dimensions of 3.67 m long, 1.83 m wide and 3.05 m deep. The frame was lined with nylon netting of 27 mm meshsize. For observational purposes, the net cage was divided into three equal quadrants (1.22m each) in the horizontal direction and three equal quadrants in the vertical direction (a total of 9 equal quadrants). The cage was supported by a floating frame that was strong enough to be used as a working platform (*Fig. 1*).

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

Lighting equipment used for the experiment consisted of a 2.2 HP electrical generator, four 150 watts' bulbs each blue, red, white and yellow, and four incandescent (white) bulbs having intensities of 150, 300, 450 and 600 watts. The light source was located 30 cm above the

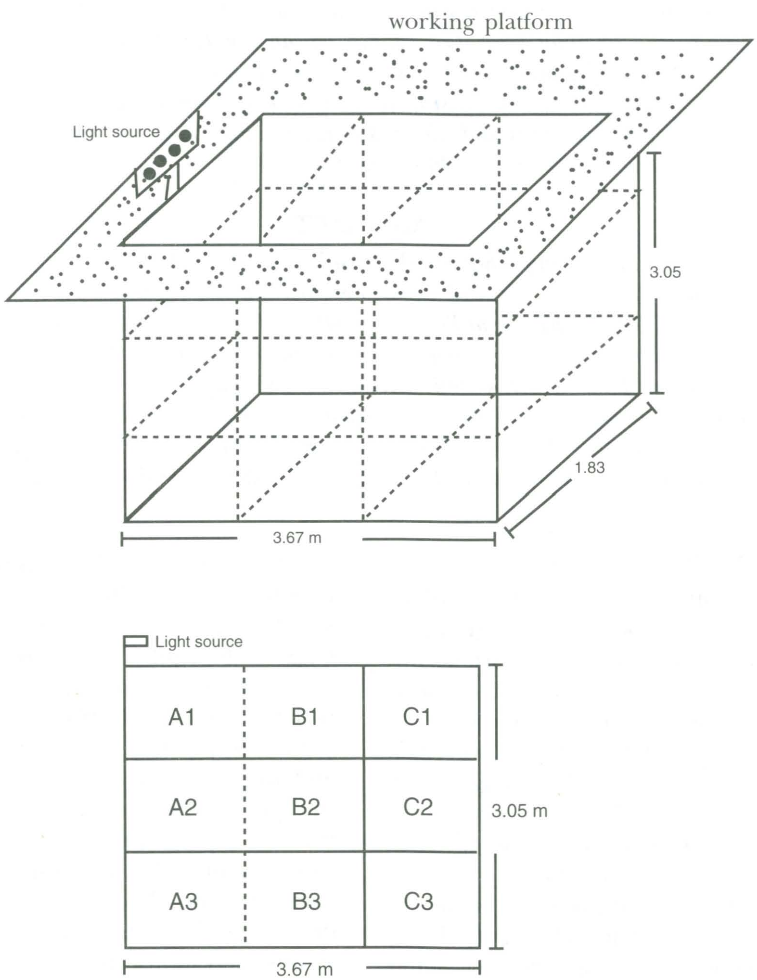

Fig 1. Configuration of the experimental cage

sea level. An electrical generator that supported the lighting system was placed in a dory at a distance of approximately 15 m away from the cage to minimize the effect of emitted noise on the squid behaviour.

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

Two observers were involved in the study to minimize observational bias. Response of squids to lights such as directions of movement, position after a period of time and other behaviours were visually observed and recorded at 0 (when light was turned on), 5th and 10th minute. Average Mean Displacement Position (AMDP) of squid in response to each characteristic of light was calculated according to Nestler *et al.* (1992). The distances from the center of all quadrants to the end of the net nearest to the light source were first calculated (Table 1). The displacement position of the squids was measured according to the quadrant of their presence. In cases where squids were found 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 divided by total number of squids. For example, if there are 7 squids in quadrant A2 and 8 squids in B2, the average distance of squid from the end of the net nearest to the light source is [(7 x 1.65)+(8 x 2.39)] / 15 = 2.04 m. Lines of isoilluminance for all degrees of intensities were first determined and these lines were coordinated with the positions of squids to determine the preferable range and peak range of illuminance for the squids.

RESULTS

Data of underwater illuminance for four different intensities of light sources are shown in Table 1. Data on the response of *Sepioteuthis lessoniana* and *Loligo chinensis* to different intensities and colours of light for each period of time are summarized in Table 2 and Table 3 respectively. Analysis of variance on the relation between AMDP of both species of squids for four different intensities of light sources (Table 2) did not show any significant difference at the period of 0 minute ($P>0.05$) but was found to be significantly different when tested at the periods of 5th and 10th minute ($P<0.05$). Regression analysis conducted for periods of 5th and 10th

TABLE 1
Underwater illuminance (lux) at the centre of all quadrants for four different intensities (watts) of light sources

Quadrant	*Distance (m)	150 w	300 w	450 w	600 w
A1	0.79	54.35	78.50	178.55	233.75
A2	1.65	14.30	32.70	78.60	127.25
A3	2.61	8.25	19.50	36.50	58.70
B1	1.91	1.00	1.95	2.40	2.25
B2	2.39	3.95	5.50	9.75	14.70
B3	3.14	1.00	3.50	6.15	13.05
C1	3.09	Not measurable	0.50	0.75	0.85
C2	3.41	Not measurable	1.50	1.65	6.60
C3	3.97	Not measurable	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
The AMDP of *S. lessoniana* and *L. chinensis* at the three periods of time for four different intensities of light sources

	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

AMDP : Average Mean Displacement Position

TABLE 3
The AMDP of S. *lessoniana* and *L. chinensis* at the three periods of time for four different colours of light sources

	S. lessoniana			*L. chinensis*		
Colours	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
Mean	2.85	2.17	2.27	2.97	2.73	2.69

AMDP : Average Mean Displacement Position

minute revealed a positive correlation between the AMDP of the squid and the intensities of light source. AMDP of squids was found to increase with the increase in intensity of light source. However, analysis of variance conducted on the relation between the AMDP of squids for four different colours of light sources (Table 3) did not show any significant difference at all the 0, 5th and 10th minute ($P>0.05$).

Relationship between underwater illuminance and the squid's occurrence is given in Table 4. It was found that the preferable range of underwater illuminance for *Sepioteuthis lessoniana* was 1.5-25.0 lux with the peak range recorded at 2.5-10.0 lux. *Loligo chinensis* recorded a preferable range of 1.5-22.5 lux and a peak range of 2.5-10.0 lux.

DISCUSSION

Knowledge on the behavioural response of squids to artificial light is very scarce. Researchers have so far conducted experiments on Japanese squid (*Todarodes pacificus*) and found the species to be easily attracted to artificial light by swimming up to the water surface towards the light source (Nomura and Yamazaki, 1977; Ben-Yami 1988). The response of *Sepioteuthis lessoniana* and *Loligo chinensis* towards artificial lights has not been fully understood. These species are found in abundance in the coastal and offshore waters of Malaysia at depths ranging from the water surface to a depth of approximately 170m. They spawn throughout the year but peaks are observed between February to May and August to November (Chotiyaputta 1982; Supongpan *et al.* 1992).

From the results of the experiments, it could be postulated that both *Sepioteuthis lessoniana* and *Loligo chinensis* are strong phototaxis animals that are easily attracted by artificial light. The response of the squids to light is due to a direct stimulus behaviour as it was observed that

TABLE 4
Range of underwater illuminance and the number of squid occurrence for different intensities of lights

Species	Intensity (watts)	Range of underwater illuminance (lux)				
		0-1.5	1.5 - 2.5	2.5 - 10.0	10.0 - 25.0	25.0 - 100.0
S. lessoniana	150	–	1.00 ± 0.63	13.83 ± 0.75	0.17 ± 0.14	–
	300	–	0.83 ± 0.75	13.83 ± 0.75	0.33 ± 0.52	–
	450	–	0.67 ± 0.82	13.83 ± 1.17	0.50 ± 0.84	–
	600	–	0.17 ± 0.41	14.17 ± 0.75	0.67 ± 0.55	–
		0 - 1.5	1.5 - 2.5	2.5 - 10.0	10.0 - 22.5	22.5 - 100.0
L. chinensis	150	–	0.83 ± 0.75	14.00 ± 0.63	0.17 ± 0.14	–
	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)

the squids would immediately lose the direction of movement when the light was switched on. Similar behaviour is also reported for some fish species. Sasaki (1953) reported that school of horse mackerel is attracted initially by light without taking any prey. The same behaviour was also described in a report by Verheijen (1958) on the systematic responses of fish to artificial light. He noted that the self controlling system of nerve center will act naturally and fish can select the appropriate degree of light intensity under natural light condition. Under artificial light condition, the self controlling system of fish is disturbed and fish lose a sense of direction and are thus easily attracted by artificial light through an action of compulsory phototaxis.

According to a theory of optimum light for aquatic animals (Inoue 1972), each species has its own preferable range of underwater illuminance. Results from this study show that *Sepioteuthis lessoniana* and *Loligo chinensis* prefer the levels of underwater light illuminance of 1.5-25.0 lux with peak range of 2.5-10.0 lux. This is in agreement with a report by Ogura *et al.* (1985) which revealed that the proper illuminance to attract Japanese squid (*Todarodes pacificus*) is approximately 10 lux. As a comparison, other marine species such as anchovy, pacific saury and mackerel prefer the underwater illuminance of 0.03-6.00 lux, 0.00-10.00 lux and 2.40-39.50 lux respectively (Inoue 1972). As squids seem to prefer underwater light illuminance similar to pacific saury, the behaviour could be manipulated for an economical multispecies harvesting technique.

Although both species of squids prefer to remain at almost similar level of underwater illuminance, their AMDP differs. Table 2 shows that the mean AMDP of *Sepioteuthis lessoniana* for all periods of time are smaller than the mean for *Loligo chinensis*. This shows that *Sepioteuthis lessoniana* prefers to remain at a shorter distance than *Loligo chinensis* when responding to the same intensity of light. It could therefore be concluded that *Sepioteuthis lessoniana* has a stronger positive phototactic behaviour than *Loligo chinensis*. This knowledge could be applied for species-selective harvesting technique. With respect to the AMDP of squids for the four different colours of lights however, no significant difference ($P>0.05$) was observed at all periods of time (Table 3). This shows that the squids are insensitive to colours.

CONCLUSION

This study reveals the importance of understanding the behaviour of squids in response to underwater illuminance of artificial light. The information gathered from the study provides the needed knowledge on the behavioural response of squid to artificial light and may pave a way for multi-species as well as species-selective harvesting techniques.

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