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# Visual field of the mud crab (*Scylla tranquebarica*), and the whiteleg shrimp, *Litopenaeus vannamei*

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## Abstract

The previous behavioural studies on vision of decapod crustaceans were often based on the assumption that the visual field of the test animals was all around and there was little or no blind area above or to the rear of the animals. In the present study, we determined the visual field of the wild captured purple mud crab (*Scylla tranquebarica*) and the farmed whiteleg shrimp (*Litopenaeus vannamei*) by eliminating the directions in which vision is anatomically blocked in all directions around the eyes. The mud crab had the visual field covering the entire visual world except for the ventral-most blind area. The whiteleg shrimp has the visual filed with a 66˚ binocular field and can see all around but is morphologically blocked by the scaphocerite extended forward between the eyes. While the transparent scaphocerites transmit 80 % of light from 400 to 700 nm wavelengths, an object seen through the scaphocerites is faded due to the light refraction, indicating that the morphological blocking is not always negligible. The trait of these visual fields should be taken into consideration in the design of visual behaviour experiments.

Keywords: Blind area, Scaphocerite, Food searching

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## Introduction

Visual perception provides an important source of behaviourally relevant information in the visual field for many animals to find food and mates, detect potential predators and threats, and notice changes in their surroundings (Ping et al., 2015). The visual field defines the space around the head of an animal from which information can be extracted at any one instant (Martin, 2014).

Aquatic and semi-terrestrial crabs do visual display in agonistic and sexual activities (Schöne, 1968; Wright, 1968) and exhibit a telotaxis toward mangroves or clumps of beach grass (Herrnkind, 1968). Animal signals can only be understood by knowing how signals are perceived and processed by signal receivers (Guilford and Dawkins, 1991). In visual signals, the visual field of a receiver should be known for better understanding of behavioural response of the receiver. The previous behavioural studies on vision of decapod crustaceans were often based on the assumption that the visual field of the test animals was all around and there was little or no blind area above or to the rear of the animals. Decapod crustaceans have a pair of stalked eye which are movable horizontally and vertically. Placing a compound eye on a stalk offers the advantage of an expanded visual field, and the stalk provides the potential for mobility of the eye as the animal or its visual targets move about (Cronin and Porter, 2008). However, so far, the visual field of the decapod crustaceans was measured only for the fiddler crab (*Uca vomeris*) where the visual field covers the entire visual space except for the ventral-most part (Smolka and Hemmi, 2009).

While a visual stimulus should be presented within the visual field of a test animal, the visual stimulus was presented without knowing the visual field of test crabs in the previous behavioural studies on vision (Bursey, 1984; Buck et al., 2003; Scarano and Tomsic, 2004; Zeil and Hemmi, 2006; Detto, 2007; Baldwin and Johnsen, 2009, 2012; Ping et al., 2015). We have examined the visual response to coloured objects for the whiteleg shrimp (*Litopenaeus vannamei*) (Kawamura et al., 2017) and mud crab (*Scylla tranquebarica*) (Kawamura et al., 2019 in submission) in laboratory, and determined their visual field before the behavioural experiments.

## Materials and Methods

The experiments were conducted at Borneo Marine Research Institute (BMRI), Universiti Malaysia Sabah in December 2015 and April 2017. All the experimental animals were cared and handled following the guidelines by the World Health Organization (WHO, Geneva, Switzerland); the Malaysian Code of Practice for the Care and Use of Animals for Scientific Purposes; and the Committee for the Update of the Guide for the Care and Use of Laboratory Animals, Institute of Laboratory Animal Research.

***Animals***

A wild captured purple mud crab (*Scylla tranquebarica*) (Male, 16 cm carapace width, 750 g body weight) was purchased from a fish market in Kota Kinabalu, Sabah, and kept in a plastic container with a biofiltration system in the laboratory. Whiteleg shrimp (*Litopenaeus vannamei*) postlarvae were obtained from the BV Shrimp Farm, Tuaran, Sabah and reared in the shrimp hatchery of BMRI.

### *Visual field measurement*

### *Mud crab*

The visual field of vertebrates is limited by the anatomical structures of the cranial bones and is not determined by the optical characteristics of the eyes. Thus, following Watanuki et al., (2000), the visual field was determined by eliminating the directions in which vision is anatomically blocked in all directions around the eyes using a laser beam pointer.

The male mud crab was placed in a semi spherical transparent glass bowl without water. Both chelae were firmly tied (Figure 1). The crab stayed motionless and kept the chelipeds, walking legs and swimming legs folded on the bottom of the glass bowl. During the measurement of the visual field, all the directions in which the laser beam was blocked were marked on the bowl. This measurement was done when the eye stalk was in various orientations such as upward and sideward. The marked area is blind area and non-marked area is the visual field. The blind area made by the extended chelipeds and walking legs was ignored and largest visual field was adopted.

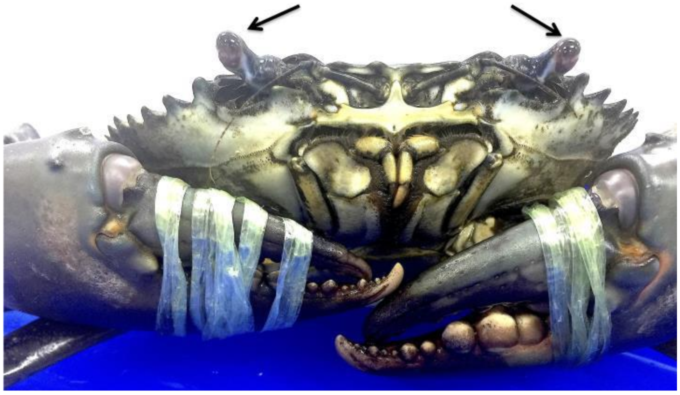

**Figure 1.** *Scylla tranquebarica* with chelae tied during the visual field measurement. Stalked eyes are indicated by arrows.

## *Whiteleg shrimp*

The directions in which vision is anatomically blocked in all directions around the eyes were determined by using photographs of 20 free swimming juveniles (4.8–5.2 total length, 8.4–9.2 g body weight) in aquaria. The whiteleg shrimp in its usual food searching crawls and swims with the head up on the aquarium bottom (Figure 2) and, due to this posture, can see back because the abdominal segments do not block vision. During this food searching motion, a pair of the scaphocerite extends forward between the eyes (Figures 3A, 3B), an object seen through the scaphocerites is faded due to their light refraction (Figure 3B), and seems to block the visual field of the whiteleg shrimp. Therefore, to confirm this possibility, the light transmittance spectrum of the fresh scaphocerite was measured with a spectroradiometer (HSR-810, Maki, Hamamatsu, Japan). The primary function of the scaphocerite is as a lateral stabilizing fin. Its articulation enables it to be moved laterally during the "backward flip" escape reaction, but this has not been demonstrated (Dall et al., 1990).

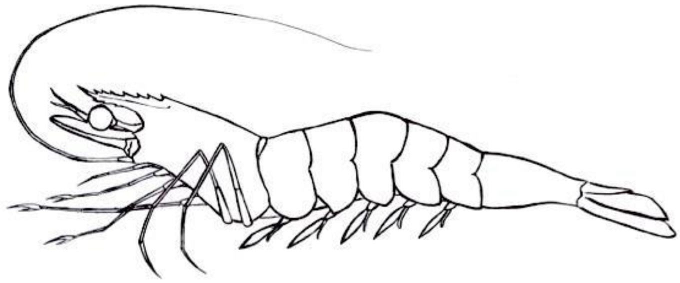

**Figure 2.** *Litopenaeus vannamei* in usual food search posture.

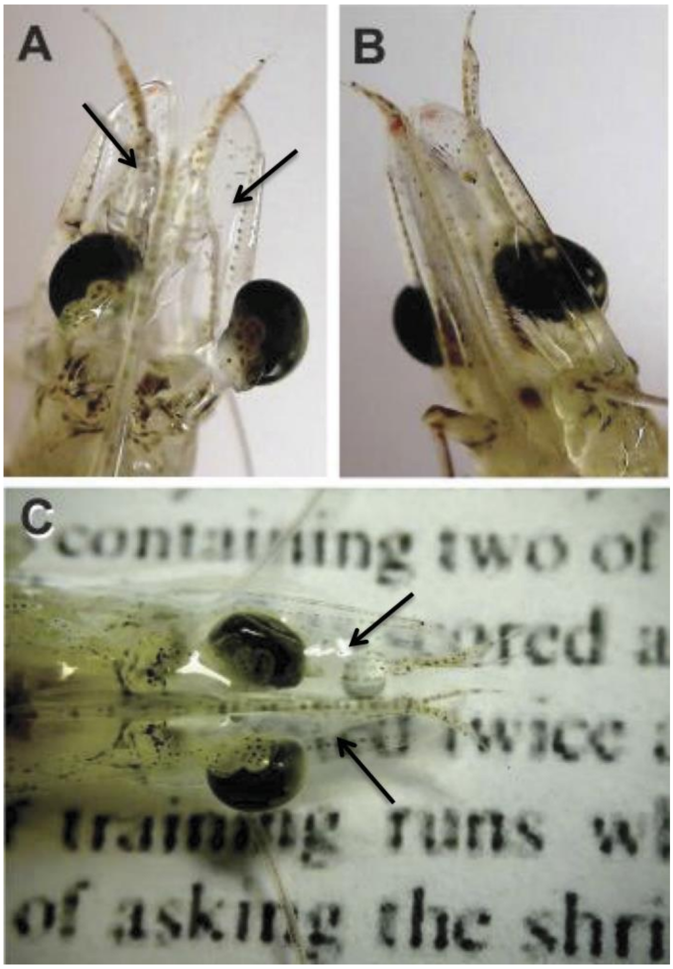


**Figure 3.** *Litopenaeus vannamei*. Dorsal (A) and ventral (B) views of a free swimming animal showing the scaphocerites between two eyes and photographs showing faded images through the scaphocerites of a fresh animal (C). Arrows show the scaphocerites.

## Results and Discussion

### *Mud crab*

Figure 4 shows the visual field covering the entire visual world except for the ventral-most blind area. While the mud crab can see all around, the behavioural response to a visual object varies depending on the position of the object in the visual filed. The mud crab display an agonistic behaviour with chelae and chelipeds opened in response to a threatening visual object approaching the frontal visual field. But it does not display this agonistic behaviour and rather folds the walking legs and squats down on the tank bottom in response to the object approaching in the rear visual field (Kawamura, personal observation). This indicates the difficulty of behavioural determination of the visual field of the mud crab. However, we may be able to know how the crab perceives different visual objects that elicit a different response. The dactylus of the swimming legs is chemosensitive and is involved in feeding (Kawamura et al., 2019 in submission). The ability to see backward is important in detecting food by vision.

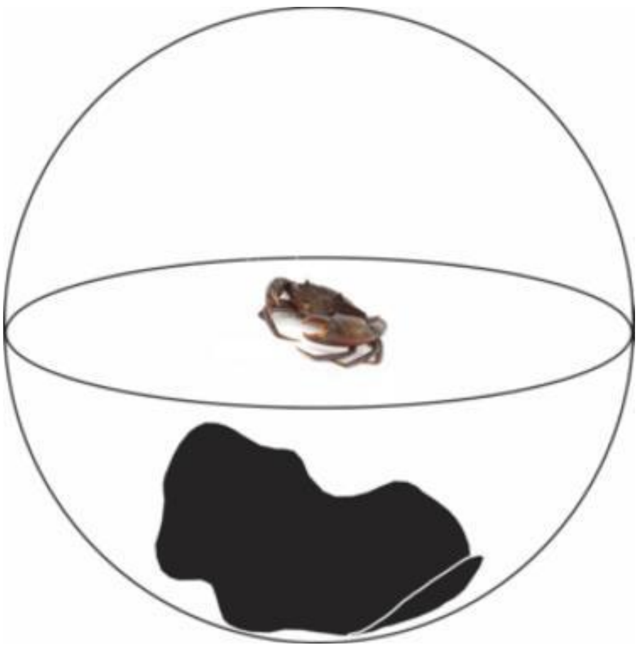

**Figure 4.** *Scylla tranquebarica* - showing the visual field covering entire visual world except for the ventral most blind area (black region).

### *Whiteleg shrimp*

This study shows that a pair of the scaphocerite blocks the visual field and the frontal binocular visual field is at the angle of 66° (Figure 5). The binocular field is much wider than the acute zone 15-20° of mysis shrimp (*Dioptromysis paucispinosa*) (Nilsson and Modlin, 1994) and the near point is short. The primary function of the scaphocerite is to act as a lateral stabilizing fin. Its articulation enables it to be moved laterally during the "backward flip" escape reaction, but this has not been demonstrated (Dall et al., 1990). The binocular field might be narrower when the scaphocerites are fully moved laterally than in the normal feeding motion shown in Figure 5.

The selective sensory ablation experiment indicated that the whiteleg shrimp primarily depends on vision in detecting food (Kawamura et al., 2017). The whiteleg shrimp is able to visually detect food in any directions in its visual field. As mentioned above, although the scaphocerites are transparent, an object seen through the scaphocerites is faded due to the light refraction.

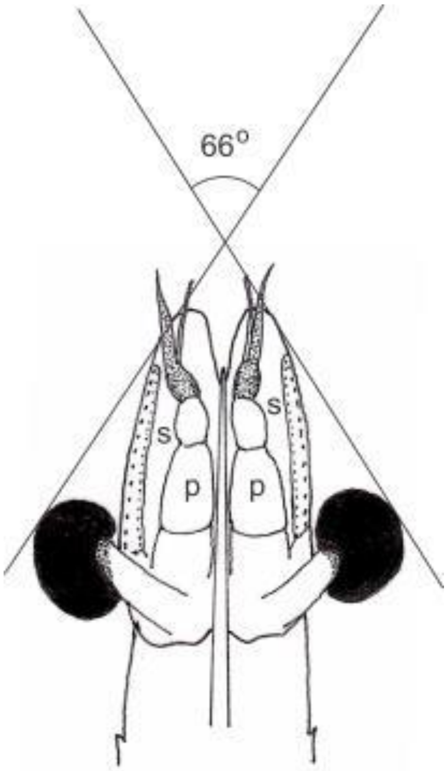


**Figure 5.** *Litopenaeus vannamei*. Visual field in the horizontal plane showing a binocular field of 66°. p, peduncle of the antennule; s, scaphocerite.

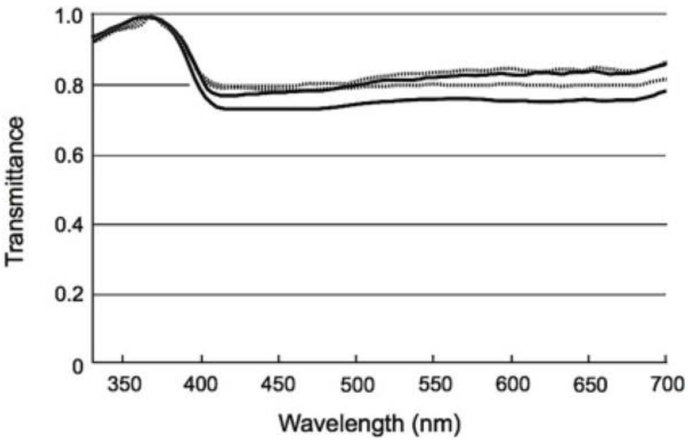


**Figure 6**. *Litopenaeus vannamei.* Light transmittance spectrum of two scaphocerites from specimens of 36 mm (dotted line) and 45 mm (solid line) in total length of *L. vannamei*.

Figure 6 shows the light transmittance spectra of a pair of the scaphocerites from two specimens of *L. vannamei*. The scaphocerites transmitted 95 % of ultraviolet radiation and about 80 % of light from 400 to 700 nm wavelengths. As mentioned above, an object seen through the scaphocerites is faded due to their light refraction (Figure 3C). Therefore, the morphological blocking is not always negligible in conducting vision experiments with the whiteleg shrimp.

The mud crab and the whiteleg shrimp had the visual field covering entire visual world except for the ventral-most blind area, which ensures full panoramic vision. However, the range of visual abilities is not uniform across the visual field, and varies from animal to animal (Perry et al., 2017). In the compound eye of the fiddler crab, the visual field has five distinct eye regions (ventral, dorsal, frontal, lateral and medial) which exhibit clear differences in sampling resolution and contrast sensitivity, and these regions are specialised to support different behavioural tasks (Smolka and Hemmi, 2009). The regional specialization of the compound eye is a subject for further investigation in order to understand visual ecology of the mud crab and the whiteleg shrimp and their behaviour.

## Conclusion

All animals rely on behaviourally relevant visual information in the visual field to guide their behaviour. However, little information is available on the visual field of decapod crustaceans. In this experiment the visual field of the purple mud crab (*Scylla tranquebarica*) and the whiteleg shrimp (*Litopenaeus vannamei*) were determined by eliminating the directions in which vision is anatomically blocked in all directions around the eyes. This enabled us to demonstrate a full panoramic vision with several limitations. The mud crab had the visual field covering the entire visual world except for the ventral-most blind area. The whiteleg shrimp have the visual filed with a 66˚ binocular field and can see all around but is morphologically blocked by the scaphocerite extended forward between the eyes. While the transparent scaphocerites transmit 80 % of visible light, an object seen through the scaphocerites is faded due to the light refraction.

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