Shelter Color Selection of Juvenile Swimming Crabs (Portunus trituberculatus)

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Abstract: Color preference testing for animals is a prerequisite for optimizing facilities and ensuring animal welfare in aquaculture. Swimming crabs (Portunus trituberculatus) are aggressive, and shelters are often installed in ponds to reduce the high mortality rate caused by their agonistic behavior. To test the preference of juvenile crabs for the color of shelters, this study observes the preferences of crabs for shelters of different colors (white, yellow, blue, and black). The counts and duration of crabs occupying different colored shelters were quantified. The probability of fighting and the probability of abandoning the shelter were also calculated. The results revealed that: (i) when all colors were presented simultaneously, the $z$-scores of the blue shelters were far higher than others during the day; (ii) when only one color was present, crabs occupied the blue shelter significantly more often and for longer periods of time during the day, with invasive crabs exacerbating this preference; and (iii) the probability of fighting between crabs was relatively low in the presence of the blue shelter, and the probability of abandoning the shelter was significantly lower than that of others. Based on these results, blue shelters are recommended for use in swimming crab ponds.

Keywords: pond culture; swimming crab; preference test; shelter color

1. Introduction

Shelters have been widely used in the pond cultures of swimming crabs (Portunus trituberculatus) as an important aquaculture facility [1–3]. Research has confirmed that ponds with a stated density of shelters on the bottom can reduce the probability of encounters between individuals and effectively prevent fights [4,5]. The shelter’s material, size, structure, and other properties all affect aquaculture benefits [6–8]. In a previous study [9], the authors found that swimming crab juveniles preferred circular shelters. However, their color preferences are unclear, although color is an important physical property of shelters.

In studies of other cultured species, it has been found that providing shelter in their preferred color is more conducive to their survival success, animal welfare, and economic advantages [10–13]. For example, the survival rate of the purple mud crab (Scylla tranquebarica) can be improved by providing their preferred blue shelter, which can prolong their residence time in the shelter and reduce the probability of fighting with other individuals [14]. This may be related to the fact that the preferred color of aquatic animals can effectively alleviate the environmental stress they are subjected to, reducing their aggression and allowing ingested energy to be directed towards growth [15–17].

For swimming crabs (P. trituberculatus), no color preferences have been reported for juveniles. However, juveniles have the potential to differentiate colors. Most species of the family Portunidae have very similar visual pigment systems, with absorption peaking near 500 nm [18]. This implies that swimming crabs have different sensitivities to colors, which is behaviorally evidenced by their varying tendencies to colored light [19]. Therefore, it is feasible to explore the preference of swimming crabs for shelter color through...
behavioral experiments. In this study, an animal behavioral capture system with black, blue, yellow, and white circular shelters was constructed in the laboratory to investigate the color selection of juvenile swimming crabs when shelters of different colors were simultaneously presented. The behavior of crabs occupying shelters and their behavior after encounters with invaders were also investigated when only one color of shelter was present. The results of this study will inform the optimization of aquaculture facilities for swimming crabs.

2. Materials and Methods
2.1. Animal Collection and Maintenance

The experiment was performed at the Key Laboratory of Mariculture, Ministry of Education, Ocean University of China, Qingdao, China. Male juvenile swimming crabs were obtained from a breeding base in Jiaonan and were separately housed in aquariums (18.72 L, 32.5 × 24 × 24 cm) for ten days after transportation. The aquariums were isolated from each other to prevent any interaction between the crabs. The crabs were maintained in seawater with sand filtration, and the aquariums were aerated throughout the day during the acclimatization. Seawater temperature ranged from 20 to 22 °C, and the salinity ranged from 29 to 31%. The photoperiod of the room was 12 h/12 h light/dark. A sufficient amount of Manila clams (*Ruditapes philippinarum*) was fed into the aquarium at 19:00 on a daily basis. The leftovers and feces were removed, and half of the volume of seawater was exchanged at 7:00 the next day.

2.2. Construction of the Animal Behavioral Capture System

To observe the behavior of swimming crabs and test their shelter color preferences, an animal behavioral capture system was constructed in an interference-free room with a 12 h/12 h light/dark photoperiod regime (Figure 1). The system was comprised of an aquarium and a video capture system. The experimental aquarium (d = 120 cm, h = 120 cm) was made of smooth white fiberglass and was used as the arena for the preference tests of crabs [9]. Sand-filtered seawater (temperature 21 ± 1 °C, salinity 30 ± 1) in the aquarium was kept at a height of 30 cm and was not aerated. The video capture system used to record the activities of crabs consisted of an infrared camera (Hikvision, DS-IPC-B12HV2-1A, Shenzhen, China, infrared wavelength = 850 nm), a monitor (Skyworth, F24G1V, Shenzhen, China), and a video recorder (Hikvision, DS-7808N-K1/8P, Shenzhen, China). The infrared camera was set 60 cm above the experimental aquarium.

![Animal behavioral capture system](image)

**Figure 1.** Animal behavioral capture system: infrared camera (A), experimental aquarium (B), monitor (C), and video recorder (D).
2.3. Construction of Shelters

Identical circular shelters (d = 16 cm, l = 10 cm) were made using PVC (Huaya, Kunshan, China) (Figure 2A). Each shelter had openings at both ends. Both the interior and exterior surfaces were painted with acrylic paint (Marley A-1100) in either black (RGB: 0, 0, 0), blue (RGB: 37, 75, 174), yellow (RGB: 254, 196, 0), or white (RGB: 255, 255, 255). Before the experiment, the visible irradiance of the underwater shelters of different colors was measured using a hyperspectrometer (RAMSES-ARC, Rastede, Germany) to gauge the relative visibility. The sensor of the hyperspectrometer was placed inside the experimental aquarium at a distance of 40 cm to measure the irradiance of the inner wall as a background control. Shelters of all four colors were subsequently placed in the aquarium, and each color’s irradiance was measured at the same distance underwater (Figure 3).

![Figure 2.](#) The circular shelter (A), a vertical view of the experimental aquarium with different colored shelters (B), and a vertical view of the experimental aquarium with one colored shelter (C).

![Figure 3.](#) Underwater visible irradiance of four shelters.

2.4. Experimental Design

Two experiments were carried out in the laboratory to investigate the shelter color preference of swimming crabs and the effect of color on their behavior.

2.4.1. Experiment One—Preference Test of Swimming Crabs for Different Colored Shelters

In the animal behavioral capture system, four color shelters—black, blue, yellow, and white—were attached at equal distances to the bottom of the experimental aquarium. One opening of each shelter was tightly fixed against the inside of the aquarium, and
the opposite opening faced the center of the aquarium. The gap between the shelter and the aquarium was sealed with waterproof tape to prevent crabs from resting in it. (Figure 2B). In this experiment, twelve sets of behavioral capture systems were constructed. The effect of the color sequence was reduced by random variation in the shelter position in each system.

Healthy male swimming crab juveniles (carapace width = 97.31 ± 4.62 mm, n = 24) in the intermolt period were chosen as experimental subjects after ten days of acclimation. Before the experiment started, the experimental crabs were not fed for one day. Since the behavior of swimming crabs may be disturbed by conspecifics [20], invasive crabs were introduced in this experiment to investigate the influence of other individuals on the crabs’ color preferences for shelter. The crabs were matched in pairs and the difference between the carapace width size of each pair did not exceed 5%. One of the two crabs was randomly chosen as the focal crab, and the top of its carapace was painted with a white circle (Marley A-1100) to distinguish it during observation. Another crab was considered an invasive crab and not marked. Each behavioral capture system was used to recording the activities and interactions of a pair of crabs.

Before the recording started, a cage was positioned in the center of the bottom of the aquarium. The focal crab was gently placed in the cage at 9:00. The cage was lifted after 10 min, and the recording started. After recording the behavior of the focal crab for 24 h, the invasive crab was carefully put in the center of the aquarium. The experiment was completed after recording the behavior of the pair for 24 h. There was no displacement of the shelters and no crab mortality during the experiment. No crabs were reused throughout the experiment.

2.4.2. Experiment Two—Effect of Shelter Color on the Occupation of Shelters by Swimming Crab

To investigate the effect of shelter color on swimming crab behavior, four types of behavioral capture systems were constructed (Figure 2B). Each system had one shelter fixed on the bottom of the aquarium at a random site. The color of the shelter in each type of system was black, blue, yellow, and white, respectively. In this experiment, six identical systems of each type were constructed. Healthy male swimming crab juveniles (carapace width = 95.74 ± 4.85 mm, n = 48) without reuse were used for the experiment. The fixation of the shelter, matching of crabs, marking method, placement time of invasive crabs, and video recording were the same as described in Experiment One. There was no displacement of the shelters and no crab mortality during the experiment.

2.5. Calculated Parameters

The behavior of swimming crab juveniles showed periodic differences due to the influence of diurnal variation and conspecifics. For this reason, the videos were partitioned into four time periods [9]. The videos were separated into two segments, named Day 1 and Day 2, based on the time when the invasive crab was added. Then, the videos of each segment were split into two time periods, daytime (9:00–21:00) and nighttime (21:00–9:00), according to the illumination. As the primary subjects, the behavioral data of the focal crabs during each time period were quantified and analyzed.

2.5.1. Occupation of the Shelter

The residence of focal crabs in the shelters was observed. When all or part of its body was inside a shelter, the crab was considered as occupying that shelter. Our previous study found that the preference of crabs for different shelters can be measured by z-scores [9]. Z-scores can quantify the preference of the crab for the shelter, with higher z-scores indicating a greater preference for this type of shelter. Z-scores were obtained by calculating the occupation of each shelter and transforming them into a ratio; refer to Zhang et.al [9] for the detailed calculation. In Experiment One, the counts of occupation were calculated and the z-scores of the counts of each shelter were obtained separately for each period.
z-scores of the duration of each shelter were obtained in the same way. In Experiment Two, the sum of the counts and duration of occupation of the same color shelter in each period was calculated respectively.

2.5.2. The Probability of Fighting upon Encounter

When physical contact was made between the focal crab and the invasive crab in the aquarium, it was counted as an encounter [21]. If the encounter was followed by an attack by the focal crab on the invasive crab, such as striking, grabbing, or chasing, it was counted as a fight [22]. In Experiment Two, the probability of fighting between two crabs was calculated as (the count of fights)/(the count of encounters).

2.5.3. The Probability of Abandoning the Shelter

A focal crab already staying in the shelter may encounter an invasive crab trying to occupy the shelter. If the focal crab evacuated the shelter after meeting the invader inside the shelter, it was counted as an abandonment of the shelter. In Experiment Two, the probability of abandonment of the shelter by the focal crab was calculated as (the counts of abandonment)/(the counts of encounters with the invasive crab in the shelter).

2.6. Statistical Analysis

In Experiment One, the Kruskal-Wallis test was used to compare the differences in the z-scores of the counts and the z-scores of the duration of occupation during each period. In Experiment Two, a one-way ANOVA was used to compare the differences in the counts of and duration of occupation in each period, with color as a fixed factor. The probability of fighting and the probability of abandoning the shelter upon encounter were also analyzed separately by one-way ANOVA. Multiple comparisons were performed using Duncan’s test when significant differences were found among different colors. Levene’s test was used to test the assumption of homogeneity of variance, and the Shapiro-Wilk test was used to test the normality of the data. The data were square-root-transformed when heteroscedasticity was significant. A significant level of difference of \( p < 0.05 \) was used for all analyses. To ensure uniformity in the reporting, \( p \) values smaller than 0.001 were reported as \( p = 0.001 \). All statistical analyses were performed using SPSS 27.0 (IBM Corporation, New Orchard Road, Armonk, NY, USA).

3. Results

3.1. Experiment One—Preference Test of Swimming Crabs for Different Colored Shelters

3.1.1. Z-Scores for the Counts of Occupation

In the daytime of Day 1, the shelter color significantly affected the z-scores of the counts of occupation (Figure 4A, \( H = 8.549, p = 0.036 \)). The z-scores of the blue shelter were far higher than those of the yellow shelter. The difference between the z-scores of the white and black shelters was not statistically significant. The differences between the z-scores of the white, yellow, and black shelters were not statistically significant. There was no significant effect of shelter color on the z-scores of the counts of occupation in the nighttime of Day 1, with an absence of statistical differences among the z-scores of the different colored shelters (Figure 4B, \( H = 5.828, p = 0.120 \)).

In the daytime of Day 2, the shelter color significantly affected the z-scores of the counts of occupation (Figure 4C, \( H = 14.566, p = 0.002 \)). The z-scores of the blue shelter were far higher than those of the white and yellow shelters, and the difference between those of the black shelter was not significant. The difference between those of the white, yellow, and black shelters was not significant. There was no significant effect of shelter color on the z-scores of the counts of occupation in the nighttime of Day 2, with an absence of statistical differences among the z-scores of the different colored shelters (Figure 4D, \( H = 5.630, p = 0.131 \)).
3.1.2. Z-Scores for the Duration of Occupation

In the daytime of Day 1, shelter color significantly affected the z-scores of the duration of occupation (Figure 5A, $H = 14.550$, $p = 0.006$). The z-scores of the blue shelter were far higher than those of the yellow shelter, and the difference between those of the white and black shelters was not significant; the difference between those of the white, yellow, and black shelters was not significant. There was no significant effect of shelter color on the z-scores of the duration of occupation in the nighttime of Day 1, with an absence of statistical differences among the z-scores of the different colored shelters (Figure 5B, $H = 6.030$, $p = 0.110$).

In the daytime of Day 2, the shelter color significantly affected the z-scores of the duration of occupation (Figure 5C, $H = 19.857$, $p = 0.001$). The z-scores of the blue shelter were significantly higher than those of the white and yellow shelters, and the difference between those of the black shelter was not significant; the difference between the z-scores of the white, yellow, and black shelters was not significant. There was no significant effect of shelter color on the z-scores of the duration of occupation in the nighttime of Day 2, with an absence of statistical differences among the z-scores of the different colored shelters (Figure 5D, $H = 4.338$, $p = 0.227$).

3.2. Experiment Two—Effect of Shelter Color on the Occupation of Shelters by Swimming Crabs

3.2.1. Counts of Occupation

On Day 1, shelter color did not affect the counts of occupation, for either daytime (Figure 6A, $F_{3,20} = 0.769$, $p = 0.525$) or nighttime (Figure 6B, $F_{3,20} = 0.641$, $p = 0.598$). In the daytime of Day 2, the counts of occupation were significantly influenced by the shelter color (Figure 6C, $F_{3,20} = 8.372$, $p = 0.001$). The focal crab occupied the blue shelter far more often than the white, yellow, and black shelters; it occupied the white shelter obviously
more often than the yellow shelter, and the difference between the counts of it occupying the white and black shelters was not significant. The difference between the counts of crabs occupying the yellow and black shelters was not significant. In the nighttime of Day 2, the counts of occupation were significantly influenced by the shelter color (Figure 6D, $F_{3,20} = 3.906$, $p = 0.024$). The focal crab occupied the blue and black shelters observably more often than the yellow shelter. The difference between the counts of crabs occupying the white, blue, and black shelters was not significant; the difference between the counts of crabs occupying white and yellow shelters was not significant.

3.2.2. Duration of Occupation

On Day 1, shelter color did not influence the duration of occupation, for either daytime (Figure 7A, $F_{3,20} = 1.064$, $p = 0.386$) or nighttime (Figure 7B, $F_{3,20} = 1.440$, $p = 0.261$). In the daytime of Day 2, the duration of occupation was significantly influenced by the shelter color (Figure 7C, $F_{3,20} = 5.814$, $p = 0.005$). The focal crab occupied the blue shelter far longer than the yellow and black shelters, but its occupation did not obviously differ from the white shelter; it occupied the white shelter significantly longer than the yellow shelter, but it did not obviously differ from the black shelter. There was no significant difference between the duration of occupying the yellow and black shelters. There was no obvious effect of shelter color on the duration of occupation in the nighttime of Day 2, with an absence of statistical differences among the duration it occupied the different colored shelters (Figure 7D, $F_{3,20} = 2.178$, $p = 0.122$).
Figure 6. The counts of occupation of different colored shelters: the daytime of Day 1 (A), the nighttime of Day 1 (B), the daytime of Day 2 (C), and the nighttime of Day 2 (D). Each colored point represents the count of occupation in each system. Different lowercase letters represent statistically significant differences in the counts of occupation ($p < 0.05$).

Figure 7. The duration of occupation of different colored shelters: the daytime of Day 1 (A), the nighttime of Day 1 (B), the daytime of Day 2 (C), and the nighttime of Day 2 (D). Each colored point represents the duration of occupation in each system. Different lowercase letters represent statistically significant differences in the duration of occupation ($p < 0.05$).
3.2.3. The Probability of Fighting and the Probability of Abandoning the Shelter

The shelter color significantly influenced the fighting probability of the focal crab, after an encounter with the invader (Figure 8A, $F_{3,20} = 6.040, p = 0.004$). The fighting probability within the black shelter system was far higher than that of the yellow and blue shelter systems, and the difference from the white shelter system was not significant. The probability of fighting within the white shelter system was significantly higher than that of the yellow shelter system, and the difference with the blue shelter system was not significant. The difference between the probability of fighting within the yellow and blue shelter systems was not significant.

![Figure 8](image)

The focal crab did not have any encounters with others inside the shelter in one system of the yellow shelter. Thus, a total of 23 systems of 24 systems were observed in this experiment where the focal crab met the invader inside of the shelter. The shelter color greatly influenced the probability of abandoning the shelter by the focal crab (Figure 8B, $F_{3,10} = 8.183, p = 0.001$). The probability of abandoning white and yellow shelters was significantly higher than that of blue and black shelters. The difference between the probability of abandoning white and yellow shelters was not significant. The difference between the probability of abandoning blue and black shelters was not significant.

4. Discussion

Swimming crabs in this study showed an overt preference for the blue shelter. The results showed that, among the white, yellow, blue, and black shelters, the swimming crab had the strongest tendency to occupy the blue shelters (Figures 4, 5 and 8B), with the highest count and duration of occupying blue shelters among the four colors (Figures 6 and 7). The presence of conspecifics exacerbated their preference for the blue shelter. The probability of fighting was relatively low in the blue shelter system (Figure 8A). Therefore, we suggest that the blue shelter is the best choice for pond culture, considering the occupation preference and fight probability. However, in contrast to the conclusion of this study, Shi et al. found that the larvae of the swimming crab preferred a white tank background. Developmental alterations in phototropism may cause this difference in color preference [23]. The larvae of most decapod crustaceans are planktonic, with positive phototropism and a simple apposition eye. When they transform into the benthic living stage, they have negative phototropism with complex superposition eyes [24]. Juvenile swimming crabs were used in this experiment, and their eye morphology and lifestyle differ from the larval period, showing a switch in color preference [25]. Consistent with the findings of this experiment, Kawamura et al. demonstrated that the color preference of the giant freshwater prawn (*Macrobrachium rosenbergii*) changed from yellow to black after metamorphosis [26].
It has been found that many crustaceans can distinguish colors [27–29]. However, this ability does not mean that they have color vision [30]. There are two types of photoreceptor cells in the compound eye of swimming crabs that can constitute two photoreceptors with different spectral sensitivities [31,32]. Therefore, swimming crabs have the physiological basis for developing color vision. This study’s visibility measurements of four colors underwater show that the yellow and white shelters are more easily detected (Figure 3), indicating that the color preference of the crab is not influenced by visibility but is more likely based on the color in itself. The preference of the crab for the blue shelter in the dark was reduced (Figures 4 and 5), possibly due to the influence of environmental brightness on its ability to discriminate colors [29]. It has been reported that swimming crabs are more likely to detect and be more inclined towards blue light at a high brightness [19]. This also supports the view that the blue color preference of swimming crabs may be due to their color vision.

This experiment found that the swimming crab’s preference for the color blue may be related to its natural habitat. One hypothesis about color preference suggests that the visual pigments of animals match the spectral distribution in their habitat and that animals are more sensitive and responsive to the spectrum of light in their habitat [33,34]. As a marine species, the swimming crab may be most sensitive to wavelengths of blue light penetrating clear water, which may account for its preference for blue shelters. This is consistent with the conclusions of Johnson et al. [35]. After testing the spectral sensitivity of five marine decapods, they found that the coastal species were sensitive to longer wavelengths of light. In comparison, the species in deep water were more sensitive to shorter wavelengths of blue and violet. Therefore, based on the results of this study, it is recommended that blue shelters be selected for swimming crab pond production to prolong the time that crabs stay inside their shelters to obtain better culture results.

In recent years, new aquaculture models have been explored to minimize cannibalism in swimming crabs. According to Wang et al., moniculture is highly productive and efficient [36]. In moniculture, each crab is kept in a plastic basket or other containers starting from the fattening period, eliminating any contact with other individuals. The survival rate and integrity of crabs in moniculture were reported to be significantly higher than in traditional ponds and polyculture systems [37]. However, the space inside the container is confined, which acts as a continuous environmental stressor and negatively affects the crab’s health [38]. Xu et al. [39] found that swimming crabs in moniculture showed adverse responses in smaller spaces, such as decreased feeding, a decreased molting rate, and a decreased body weight growth rate, together with increased activity of protective enzymes in their bodies. The white containers used by Wang et al. [36] differed significantly from the body color of the juveniles, potentially increasing the stress that the crab suffers to a certain extent [23]. Suitable background colors in aquaculture can neutralize adverse environmental stress and reduce the aggressiveness of cultured animals [40,41]. Based on the results of this experiment, the blue container preferred by swimming crabs may be more appropriate in monocultures. It may alleviate the stress experienced by the crabs and improve their growth. In future research, the growth data of swimming crabs under different environmental background colors should be continuously monitored, as the findings will provide a more comprehensive theoretical basis for optimizing the color of farming facilities and promoting the development of healthy cultures.

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Data Availability Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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References

1. Savolainen, R.; Ruohonen, K.; Tulonen, J. Effects of bottom substrate and presence of shelter in experimental tanks on growth and survival of signal crayfish, Pacifastacus leniusculus (Dana) juveniles. *Aquac. Res.* 2003, 34, 289–297. [CrossRef]

2. Benhaïm, D.; Leblanc, C.A.; Lucas, G. Impact of a new artificial shelter on Arctic charr (*Salvelinus alpinus*, L.) behaviour and culture performance during the endogenous feeding period. *Aquaculture* 2009, 295, 38–43. [CrossRef]

3. Liu, C.J.; Xu, W.J.; Jiang, Y.M.; He, J.; Zhou, Z.Q.; Shen, L.F. Application of anti-crippling device in “swimming crab and Japanese shrimp” breeding. *China Fish.* 2019, 7, 72–74. (In Chinese)

4. Oniam, V.; Arkronrat, W.; Mohamed, N.B. Effect of feeding frequency and various shelter of blue swimming crab larvae, *Portunus pelagicus* (Linnaeus, 1758). *Songklanakarin J. Sci. Technol.* 2015, 37, 129–134.

5. Kazuya, T.; Erika, Y.; Naoyuki, F.; Naoyuki, F.; Toshiki, N. The effects of shelter quality and prior residence on marbled crayfish (*Austrothamnus sp.*). *Appl. Anim. Behav. Sci.* 2020, 212, 1–6. [CrossRef]

6. Ravi, R.; Manisseri, M.K. Efficiency of shelters in reducing cannibalism among juveniles of the marine blue swimmer crab, *Portunus pelagicus*. *Isr. J. Aquicult. Bamid.* 2012, 64, 1–6. [CrossRef]

7. Fatihah, S.N.; Julin, H.T.; Cheng, A.C. Survival, growth, and molting frequency of mud crab *Scylla tranquebarica* juveniles at different shelter conditions. *Aquac. Aquar. Conserv. Legis.* 2017, 10, 1581–1589.

8. He, J.; Gao, Y.; Xu, W.; Yu, F.; Su, Z.; Xuan, F. Effects of different shelters on the molting, growth and culture performance of *Portunus trituberculatus*. *Aquaculture* 2017, 481, 133–139. [CrossRef]

9. Zhang, H.; Zhu, B.; Yu, L.; Liu, D.; Wang, F.; Lu, Y. Selection of shelter shape by swimming crab (*Portunus trituberculatus*). *Aquac. Rep.* 2021, 21, 100908. [CrossRef]

10. Luchiari, A.C.; Pirhonen, J. Effects of ambient colour on colour preference and growth of juvenile rainbow trout *Oncorhynchus mykiss* (Walbaum). *J. Fish Biol.* 2008, 72, 1504–1514. [CrossRef]

11. Batzina, A.C.; Sotirakoglou, K.; Karakatsouli, N. The preference of 0+ and 2+ gilthead seabream *Sparus aurata* for coloured substrates or no-substrate. *Appl. Anim. Behav. Sci.* 2014, 151, 110–116. [CrossRef]

12. Li, X.; Chi, L.; Tian, H.; Meng, L.; Zheng, J.; Gao, X.; Liu, Y. Colour preferences of juvenile turbot (*Scophthalmus maximus*). *Physiol. Behav.* 2016, 156, 64–70. [CrossRef] [PubMed]

13. McLean, E. Background color and cultured invertebrates—A review. *Aquaculture* 2021, 537, 736523. [CrossRef]

14. Kawamura, G.; Yong, A.S.K.; Roy, D.C.; Lim, L.-S. Shelter colour preference in the purple mud crab *Scylla tranquebarica* (Fabricius). *Appl. Anim. Behav. Sci.* 2020, 225, 104966. [CrossRef] [PubMed]

15. Maia, C.M.; Volpato, G.L. Environmental light color affects the stress response of Nile tilapia. *ZooKeys* 2013, 116, 64–66. [CrossRef]

16. Ravi, R.; Manisseri, M.K. Efficiency of shelters in reducing cannibalism among juveniles of the marine blue swimmer crab, *Portunus pelagicus*. *Isr. J. Aquicult. Bamid.* 2012, 64, 1–6. [CrossRef]

17. Gaffney, L.P.; Franks, B.; Weary, D.M.; von Keyserlingk, M.A. Coho salmon (*Oncorhynchus kisutch*) prefer and are less aggressive in darker environments. *PLoS ONE* 2011, 6, e151325. [CrossRef]

18. Forward, R.B.; Cronin, T.W.; Douglass, J.K. The visual pigments of crabs. *J. Comp. Physiol. 1988*, 162, 463–478. [CrossRef]

19. Zheng, W.; Luo, H. Phototropic response of *Portunus trituberculatus* to color light. *Mar. Sci.* 1979, 3, 15–18. (In Chinese)

20. Takahashi, M.; Suzuki, N.; Koga, T. Burrow defense behaviors in a sand-bubbler crab, *Scopimera globosa*, in relation to body size and prior residence. *J. Ethol.* 2001, 19, 93–96. [CrossRef]

21. Wang, M.C.; Peterson, C.H.; Kay, J. Prey size selection and bottom type influence multiple predator effects in a crab–bivalve system. *Mar. Ecol. Prog. Ser.* 2010, 409, 143–156. [CrossRef]

22. Liu, D.; Wang, F.; Yang, C.; Hu, N.; Sun, Y. Starvation and a conspecific competitor influence multiple predator effects in a swimming crab (*Portunus trituberculatus*)—Manila clam (*Ruditapes philippinarum*) foraging system. *J. Exp. Mar. Biol. Ecol.* 2017, 495, 35–42. [CrossRef]

23. Shi, C.; Wang, J.; Peng, K.; Mu, C.; Ye, Y.; Wang, C. The effect of tank colour on background preference, survival and development of larval swimming crab *Portunus trituberculatus*. *Aquaculture* 2019, 504, 454–461. [CrossRef]

24. Nilsson, D.E. Evolutionary links between vision and superposition optics in crustacean eyes. *Nature* 1983, 302, 818–821. [CrossRef]

25. Nilsson, D.E.; Hallberg, E.; Elofsson, R. The ontogenetic development of refracting superposition eyes in crustaceans: Transformation of optical design. *Tissue Cell* 1986, 18, 509–519. [CrossRef]
26. Kawamura, G.; Yong, A.S.K.; Wong, J.S.; Daning Tuzan, A.; Lim, L.S. The giant freshwater prawn *Macrobrachium rosenbergii* alters background colour preference after metamorphosis from larvae to postlarvae: In association with nature of phototaxis. *Aquac. Res.* 2020, 51, 3711–3717. [CrossRef]

27. Maciel, C.R.; Valenti, W.C. Effect of tank colour on larval performance of the Amazon River prawn *Macrobrachium amazonicum*. *Aquac. Res.* 2020, 51, 3711–3717. [CrossRef]

28. De los Santos Romero, R.; Garcia Guerrero, M.; Alpuche Osorno, J.; Cortes Jacinto, E. The effect of alpha males and shelter type on growth and survival of the longarm prawn *Macrobrachium tenellum* (Smith, 1871). *Lat. Am. J. Aquat. Res.* 2018, 46, 551–557. [CrossRef]

29. Kawamura, G.; Bagarinao, T.U.; Cheah, H.S.; Saito, H.; Yong, A.S.K.; Lim, L.-S. Behavioural evidence for colour vision determined by conditioning in the purple mud crab *Scylla tranquebarica*. *Fish. Sci.* 2020, 86, 299–305. [CrossRef]

30. Von Frisch, K. *Bees: Their Vision, Chemical Senses, and Language*, 1st ed.; Cornell University Press: Ithaca, NY, USA, 1971; pp. 1–34.

31. Yuan, W.; Chen, H.; Zhang, H.; Sheng, C. Morphology and ultrastructure of photoreceptors in *Portunus trituberculatus*. *Acta Zool. Sin.* 2001, 47, 578–582. (In Chinese)

32. Kelber, A.; Vorobyev, M.; Osorio, D. Animal colour vision—Behavioural tests and physiological concepts. *Biol. Rev.* 2003, 78, 81–118. [CrossRef] [PubMed]

33. Bayliss, L.E.; Tansley, L.K. Some new forms of visual purple found in sea fishes with a note on the visual cells of origin. *Proc. R. Soc. Lond.* 1936, 120, 95–113.

34. Clarke, G.L. On the depth at which fish can see. *Ecology* 1936, 17, 452–456. [CrossRef]

35. Johnson, M.L.; Gaten, E.; Shelton, P.M.J. Spectral sensitivities of five marine decapod crustaceans and a review of spectral sensitivity variation in relation to habitat. *J. Mar. Biol. Assoc. U. K.* 2002, 82, 835–842. [CrossRef]

36. Wang, C.; Mu, C.; Li, R.; Song, W.; Yi, X.; Han, C. Efficient production technology for monoculture of *Portunus trituberculatus*. *China Fish.* 2013, 4, 72–75. (In Chinese)

37. Shen, L.; Hong, T.; Gu, J.; Yi, X.; Liu, C.; Dai, H.; Lin, X. Research on stereoculture technology of *Portunus trituberculatus* monoculture in baskets. *Mod. Agric. Sci. Technol.* 2013, 6, 264. (In Chinese)

38. Islam, M.L.; Siddiky, M.; Yahya, K. Growth, survival and intactness of green mud crab (*Scylla Paramamosain*) broodstock under different captive grow out protocols. *SAARC J. Agri.* 2018, 16, 169–180. [CrossRef]

39. Xu, Y.; Shentu, J.; Ding, Z. Effect of stocking space size on feeding behavior and growth characteristics of *Portunus trituberculatus* in a monobasic basket culture system. *Oceanol. Limnol. Sin.* 2014, 6, 1346–1352.

40. Barcellos, L.J.G.; Kreutz, L.C.; Quevedo, R.M.; da Rosa, J.G.S.; Koakoski, G.; Centenaro, L.; Pottker, E. Influence of color background and shelter availability on jundiá (*Rhamdia quelen*) stress response. *Aquaculture* 2009, 288, 51–56. [CrossRef]

41. Amano, M.; Amiya, N.; Mizusawa, K.; Chiba, H. Effects of background color and rearing density on stress-related hormones in the juvenile Japanese eel *Anguilla japonica*. *Fish. Sci.* 2021, 87, 521–528. [CrossRef]