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Original Article

Installation of shelters on growth and survival of blue swimming crab (*Portunus pelagicus*) for development of its culture

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Abstract

The objectives of this study were to conduct experiments involving the rearing of the blue swimming crab *Portunus pelagicus* with four different types of shelters in concrete tanks: 1) 90° bent plastic plates; 2) concrete blocks; 3) PVC pipes; and 4) stems of coconut leaves. We aimed to find which methods promote growth and improve the survival of the crabs using the shelters. The results showed that the type of shelter affected the survival rate of the crabs, while the presence of these shelters in the tanks did not have any significant effect on its growth. The survival rates (mean±SD) of the crabs reared in the tanks with the stems of coconut leaves (82.2±7.7%) and 90° bent plastic plates (80.0±6.7%) were significantly higher than those using PVC pipes (66.7±6.7%) and concrete blocks (62.2±3.8%) as shelters. The differences of the effects of these four types of shelters on the survival of the crabs seem to reflect the available space provided by them to escape cannibalism. The rearing experiments of the crabs with different densities of 90° bent plastic plates as shelters (0, 1, 3, and 5 shelters/m^2) showed a significant increases in the survival rates of crabs reared for 30 to 60 days (5 shelters/m^2 71.1±3.8%, 3 shelters/m^2 77.8±7.7%, 1 shelter/m^2 62.2±3.8%, no shelter 48.9±3.8%), but the effect of the shelter on the improvement of the survival rate was less clear in the crabs reared for 60 to 90 days.

Keywords: *Portunus pelagicus*, cannibalism, shelter

1. Introduction

The blue swimming crab *Portunus pelagicus* is a commercially important species that is distributed throughout the coastal waters of tropical regions of the western Indian Ocean and the eastern Pacific. However, due to overfishing and marine pollution, the amounts of natural resources and fishery production of *P. pelagicus* have shown a downward trend in these regions since 1999 (Department of Fisheries, 2015; Food and Agriculture Organization of the United Nations [FAO], 2013). Currently, many countries actively engage in the culture of the crab and its associated research, e.g., the Philippines, Indonesia, India, Australia, Malaysia, and Thailand (Josileen & Menon, 2005; Oniam & Arkronrat, 2013; Romano & Zeng, 2008). However, the culturing techniques for *P. pelagicus* have not been sufficiently established to expand the farms on a commercial scale and cannot support farmer incomes adequately due to low productivity (Andrés, Rotllant, & Zeng, 2010; Azra & Ikhwanuddin, 2015; Liao, Wang, & Lin, 2011; Oniam, Arkronrat, & Wechakama, 2012; Ravi & Manisseri, 2013).

Previous studies on the culture of *P. pelagicus* found that some of the main causes of the low survival rate were cannibalism (Marshall, Warburton, Paterson, & Mann, 2005; Oniam, Taparhudee, Tunkijjanukij, & Musig, 2011), nutritional quality of feed (Chaiyawat, Eungrasamee, & Raksakulthai, 2008; Oniam *et al*., 2012; Soundarapandian & Dominic Arul Raja, 2008), water quality (Liao *et al*., 2011; Romano & Zeng, 2006, 2007), and quality of the bottom soil of the pond (Oniam & Arkronrat, 2013). Among these main

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causes, we focused on the impact of cannibalism on the survival of the crabs in this paper. Cannibalism is defined as the process of killing and consuming either all or part of an individual of the same species. It is commonly observed in a wide variety of animals (Elgar & Crespi, 1992), including decapod crustaceans (Abdussamad & Thampy, 1994; Amaral, Paula, Hawkins, & Jenkins, 2009; Møller, Lee, Paterson, & Mann, 2008; Shelley & Lovatelli, 2011; Shivananda, Kumarswamy, Palaksha, Sujatha, & Shankar, 2012).

Oniam *et al*. (2011) revealed that cannibalism is mainly responsible for the high mortality of *P. pelagicus* in culture, particularly in the period between 30 and 45 days after the start of culture. Although many previous studies reported that the installation of shelters in the rearing pond could significantly reduce the occurrence of cannibalism in decapod crustacean culture (Almeida, González-Gordillo, Flores, & Queiroga, 2011; Fernandez, 1999; Lovrich & Sainte-Marie, 1997; Luppi, Spivak, & Anger, 2001; Marshall *et al*., 2005; Oniam, Arkronrat, & Mohamed, 2015; Tidwell, Coyle, & Schulmeister, 1998; Ut, Le, Nghia, & Hong Hanh, 2007), few studies have found a significant reduction of cannibalism due to the shelter in the culture of *P. pelagicus*. Therefore, it is necessary to find effective shelters for the development of rearing techniques in the culture of *P. pelagicus*.

In this paper, we conducted experiments to culture *P. pelagicus* in concrete tanks with four different types of the shelters and compared their effects on the growth and survival rates of the crabs. Based on the results of the experiments, we discuss which shelter type and shelter density are most effective in reducing cannibalism in the culture of *P. pelagicus*.

2. Materials and Methods

2.1 Study site and source of the crabs used in the experiments

The experiments of this study were conducted at the hatchery of the Klongwan Fisheries Research Station (KFRS), Prachuap Khiri Khan Province, Thailand. A brood stock of *P. pelagicus* was caught by native fishermen using small-scale crab traps in the coastal area of Prachuap Bay, Prachuap Khiri Khan Province, Thailand. Female crabs with dark grey eggs were placed in 200-L fiber tanks to allow them to release eggs for hatching. They were not fed during this period. The newly hatched larvae of the crabs were transferred to 2,000-L fibre nursery tanks at a density of 100 crabs/L. They were fed initially with rotifers (*Brachionus* sp.) and diatoms (*Chaetoceros* sp.). From the zoea II stage onwards, they were fed *Artemia* nauplii until the larvae had metamorphosed to the first crab stage. They were then transferred to 400 m^2 earthen ponds (two ponds of 20 m length × 20 m width × 1 m depth) at a density of 5 crabs/m^2. At this stage, the crabs were fed shrimp feed according to Oniam *et al*. (2012) until the experiment commenced.

2.2 Experimental design and set-up

2.2.1 Experiment 1: Effects of four different types of shelters on the growth and survival of the crabs

Experiments were carried out to examine the effects of four different types of shelters on the growth and survival of the crabs. The individuals used for the experiments were reared in the earthen ponds for 30 days prior to the start of the experiments. They were collected randomly, and 18 individuals were released in each of 12 concrete tanks with dimensions of 1.5 m width × 2.5 m length × 1.2 m depth and the initial density was approximately 5 crabs/m^2. Their mean±SD carapace width and body weight were 3.6±0.6 cm and 8.0±2.3 g, respectively.

Four different types of shelters were used for the experiments: 1) plastic plates bent at 90° (20 × 30 × 10 cm) (Figure 1A); 2) concrete blocks (20 × 40 × 6.5 cm) (Figure 1B); 3) PVC pipes with a length of 30 cm and diameter of 6 inches (Figure 1C); and 4) stems of coconut leaves with an approximate length of 60 cm (Figure 1D) at 1 shelter/m^2 (3 shelters/tank). One of the four different types of shelters was placed at the bottom of each of four tanks. In this paper, the experiments with a 90° bent plastic plate, a concrete block, a PVC pipe, and coconut leaves are referred to as T1, T2, T3, and T4, respectively.

The crabs reared in the experiments were fed twice a day at 09:00 and 15:00. The diet was shrimp feed no. 4S (STARTEQC™, pellet size approximately 3.5 mm, 38% protein) at 5% of the total biomass per day.

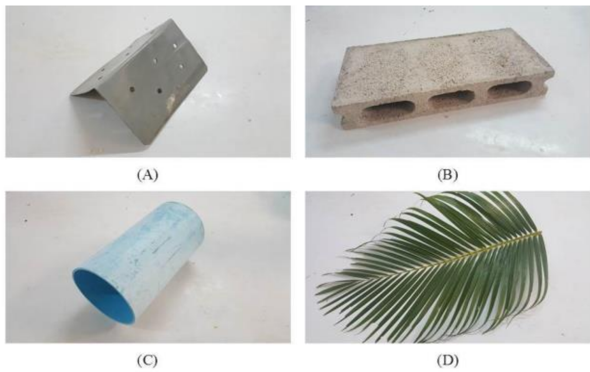

Figure 1. Four different types of shelters used in the experiments: (A) 90º bent plastic plates; (B) concrete blocks; (C) PVC pipes; and (D) stems of coconut leaves.

2.2.2 Experiment 2: Effects of the shelter density on the growth and survival of the two different size groups of the crab

The crabs used for the experiments were reared in the earthen ponds for 30 days or 60 days prior to the experiments. The crabs reared for 30 days had mean±SD carapace width and body weight of 3.4±0.7 cm and 8.3±3.1 g, respectively. Based on the results of Experiment 1, the 90° bent plastic plate showed a significant contribution to the decrease of crab mortality and was adopted as the shelter for Experiment 2. The experiments were conducted with four different shelter densities: 0; 1 shelter/m^2 (3 shelters/tank); 3 shelters/m^2 (9 shelters/tank); and 5 shelters/m^2 (15 shelters/tank) in each tank which were the Control, P1, P3, and P5, respectively, for 30 days. The shelters were individually placed at the bottom of each experimental tank. Each treatment had three replicates. The crabs were fed twice a day at 09:00 and 15:00. The diet was shrimp feed no. 4S at 5% of the total biomass per day.

The cabs reared for 60 days had mean±SD carapace width and body weight of 6.5±0.7 cm and 23.7±6.7 g, respectively. They were collected from the ponds and released into the tanks in the same manner as the 30-day experiment.

2.3 Data collection

Every 10 days in both Experiment 1 and Experiment 2, the carapace widths (the length between the tips of the epibranchial spines) of all crabs used in the experiments were measured using a caliper and the body weights were obtained using a digital balance. The survival and total mortality rates were calculated using these equations:

Survival rate (%) = (number remaining crabs/initial number of crabs) × 100

Total mortality rate (%) = 100 − Survival rate of crabs at end of experiment

During the experiments, approximately half of the water in the tank was exchanged once a week. Water quality parameters, i.e. salinity, pH, temperature, dissolved oxygen, total ammonia, nitrite, and alkalinity, were monitored biweekly. Salinity was determined using a refractometer (Primatech; Jakarta, Indonesia), and the pH of the water was measured with a portable pH meter (pH 11; Cyber Scan; Nijkerk, the Netherlands). The temperature and dissolved oxygen (DO) concentration of the water were measured using an oxygen probe (550A; YSI Inc; Yellow Springs, OH, USA), and the total ammonia, nitrite, and alkalinity of the water were determined using the indophenol blue method, the colorimetric method, and the titration method, respectively (American Public Health Association, American Water Works Association, & Water Environment Federation, 2012).

2.4 Statistical analysis

At the end of the experiments, the statistical significance of the differences in the mean survival rates among the different treatments in Experiment 1 and Experiment 2 were examined by one-way ANOVA and analyzed with Duncan's multiple range test at the 95% level of confidence. The relationships between the survival rates and number of shelters in the two crab groups (the experimental crabs reared for 30 and 60 days) were also examined using a simple linear regression analysis. All data were analyzed using the software IBM SPSS Statistics for Windows (version 21.0; IBM Corp., Armonk, NY. USA).

3. Results

3.1 Experiment 1: Effects of the four different types of shelters on the growth and survival of the crabs

The conditions of the experiments conducted in the tanks were water salinity 30.5–31.6, water temperature 28.2–29.3 °C, DO concentration 5.04–5.44 mg/L, pH 8.07–8.18, total ammonia 0.17–0.27 mg N/L, nitrite 0.07–0.15 mg N/L, and alkalinity as $CaCO_3$ 111.0–127.2 mg/L. The water conditions were not significantly different among the treatments of the four different types of shelters (P>0.05, ANOVA).

The differences in the types of shelters did not affect the growth of the crabs (P>0.05, ANOVA) in the experiments conducted for 30 days (Figure 2). However, the survival rates (mean±SD) of the crabs reared in the tanks with 90° bent plastic plates (80.0±6.7%) and coconut leaves (82.2±7.7%) as shelters were significantly higher than those in the tanks with PVC pipes (66.7±6.7%) and concrete blocks (62.2±3.8%) after 30 days (P<0.05, ANOVA). Thus, the results of the experiments demonstrated a greater advantage of the 90° bent plastic plates and coconut leaves as shelters in terms of reducing cannibalism compared to the concrete blocks and PVC pipes.

3.2 Experiment 2: Effects of the shelter density on the growth and survival of the crabs

The conditions of the experiments conducted in the tanks were water salinity 29.8–32.3, water temperature 28.2–29.3 °C, DO concentration 4.95–5.40 mg/L, pH 8.03–8.11, total ammonia 0.17–0.27 mg N/L, nitrite 0.08–0.16 mg N/L, and alkalinity as CaCO3 112.0–127.0 mg/L. The water conditions did not significantly differ among the treatments of the four different types of shelters (P>0.05, ANOVA).

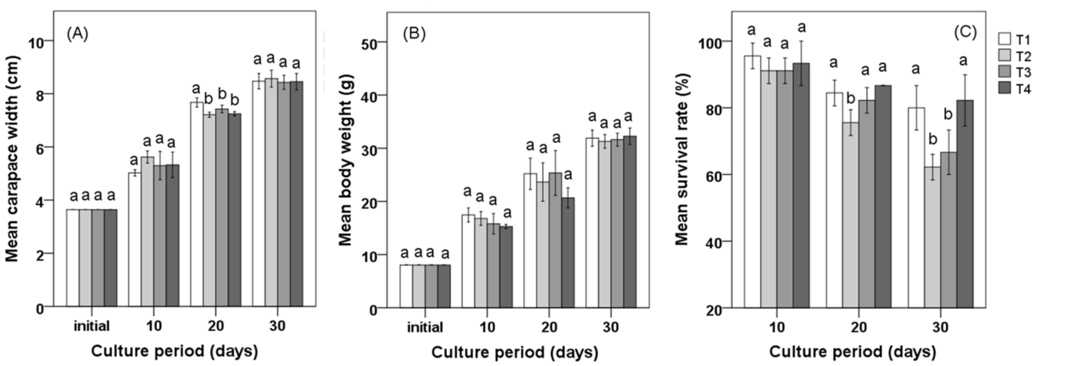

Figure 2. Experiment 1: (A) Growth in size; (B) growth in weight; and (C) survival rate of the blue swimming crab *Portunus pelagicus* reared in tanks for 30 days using the four different types of shelters of plastic plates (T1), concrete blocks (T2), PVC pipes (T3), and stems of coconut leaves (T4). These results represent the mean±SD of three replicates. The bars marked with different letters (a, b) indicate statistically significant differences (P<0.05, ANOVA).

Based on the results of Experiment 1, we chose the 90º bent plastic plate as the most effective shelter to reduce cannibalism among the crabs. The crabs reared for 30 days grew to body sizes of 29.9–31.5 g and carapace widths of 7.3–7.5 cm during the 30-day experiments. No statistically significant differences were found in the growth of the crabs among the four treatments (P0, P1, P3, and P5) with different densities of the shelter in the tanks (P>0.05, ANOVA) (Figure 3). However, the survival rates (mean±SD) of the crabs reared in treatments P1 (62.2±3.9%), P3 (71.1±3.8%), and P5 (77.8± 7.7%) were significantly higher than in P0 (48.9±3.8%). Therefore, the survival rates tended to increase as the density of the shelters increased (P<0.05, ANOVA) (Figure 4).

The results of Experiment 2 with the crabs reared for 60 days also demonstrated that the density of the shelter did not affect the growth of the crabs, but the presence of the shelter significantly increased the survival rates (mean±SD) of the crabs in the P3 treatments (88.9±7.7%) and P5 (91.1±3.8%) compared to P0 (75.6±3.9%) (P<0.05, ANOVA) (Figure 4).

Thus, the results of the experiments demonstrated that the mortality occurred more intensively in the crabs reared for 30 days (Figure 4), but it decreased simply through the presence of a higher shelter density in the tanks in both experiments with the crabs reared for 30 days and 60 days (Figures 5 and 6).

4. Discussion

In this study, the rearing experiments of the crab *P. pelagicus* using the stems of coconut leaves and 90° bent plastic plates as shelters resulted in a significant increase in the survival rates of the crabs (82.2±7.7% and 80.0±6.7%, respectively) compared to those using PVC pipes (66.7±6.7%) and concrete blocks (62.2±3.8%) as shelters. These results seem to be partly caused by the larger protective areas provided by the coconut leaves and 90° bent plastic plates than those provided by the PVC pipes and concrete blocks. The results of the experiments in this study, in which the mortality rate tended to decrease depending on the available protective area, agreed with those of previous studies on other decapod crustaceans (Almeida *et al*., 2011; Fernandez, 1999; Lovrich & Sainte-Marie, 1997; Luppi *et al*., 2001; Mirera and Moksnes, 2013; Tidwell *et al*., 1998; Ut *et al*., 2007). This may be due to the reduction in cannibalism, which is similar to the results of studies conducted by Luppi *et al*. (2001) and Ut *et al*. (2007). Thus, providing shelters to crabs reared on aquaculture farms will likely result in significant positive effects on their survival.

The results of Experiment 2 showed that the survival rates of the crabs increased simply as a result of the density of the shelters in the tank, which resulted in an increase in the total protective space available for the crabs. It is likely that a higher availability of shelters makes it easier for the crabs to maintain their distance from other individuals and decreases the chances of encountering them. At the same time, the occurrence of cannibalism in *P. pelagicus* culture seems to be significantly mitigated as the number of shelters increased in the culture facility. Based on the study results, we recommend setting the density of shelters to more than three shelters/m^2 in the crab culture to significantly decrease the mortality by cannibalism since the number of shelters was related to crab survival.

The results of this study indicate that the installation of the shelter on the bottom of the pond is an effective way of increasing the survival rate of *P. pelagicus*, and the types and density of the shelters also affected the survival rates of the crabs. In addition, the mortality rate of this crab due to cannibalism tended to decrease according to age because smaller crabs have a higher moulting frequency (Marshall *et al*., 2005).

Further studies using various shelters should be carried out in ponds to ascertain the usefulness of the shelters for rearing of *P. pelagicus*. More extensive research is still needed to study the factors related to the available space of the shelters, e.g., the shape of the shelter (height, width, and the ratio of height and width) on cannibalism to develop alternatives for crab production.

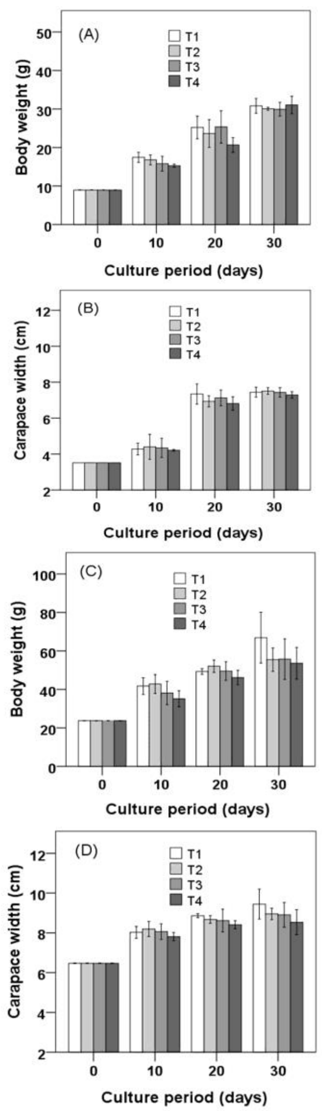

Figure 3. Experiment 2: Growth of the crab *Portunus pelagicus* reared for 30 days (A and B) and 60 days (C and D) during the period of the experi-ments for 30 days.

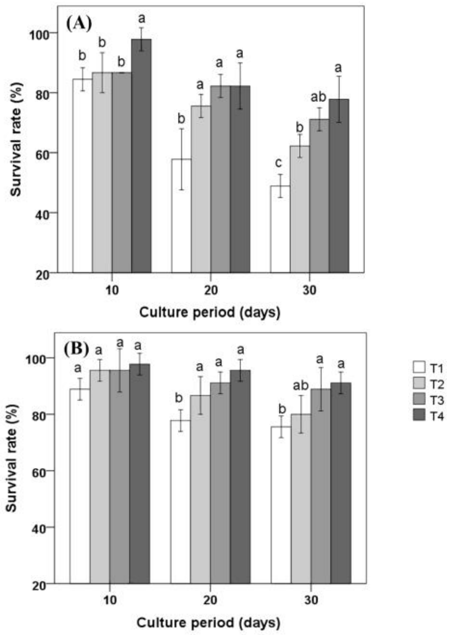

Figure 4. Experiment 2: Changes in the survival rates of the crab *Portunus pelagicus* over 30 days in the experiments. (A) Individuals reared for 30 days and (B) individuals reared for 60 days prior to the experiments. These results represent the mean±SD of three replicates. The bars marked with different letters (a,b,c) indicate statistically significant differences (P<0.05, ANOVA).

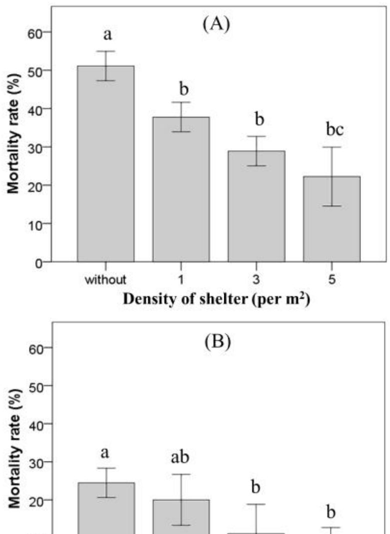

Figure 5. The mortality rates of the crabs in the tanks with four different densities of shelters over 30 days. (A) Individuals reared for 30 days and (B) individuals reared for 60 days prior to the experiments. These results represent the mean±SD of three replicates. The bars marked with different letters (a,b,c) indicate statistically significant differences (P<0.05, ANOVA).

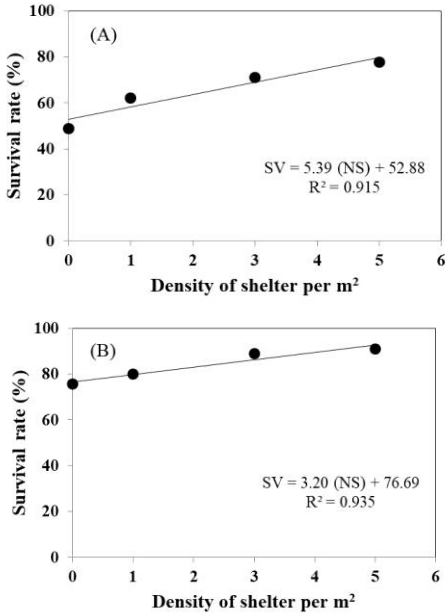

Figure 6. Experiment 2: Relationships between the shelter density (NS) and the survival rate of the crab *Portunus pelagicus* (SV) in the experiments. (A) Individuals reared for 30 days and (B) individuals reared for 60 days prior to the experiments.

5. Conclusions

The experiments conducted in this study confirmed that different types of shelters affected the survival rates of the blue swimming crab *P. pelagicus* reared in culture ponds but did not affect their growth. The survival rates of the crabs reared with the stems of coconut leaves and 90º bent plastic plates as shelters placed on the bottom of the pond were significantly higher than shelters of PVC pipes and concrete blocks, while the presence of these shelters did not promote their growth. The results of the rearing experiments involving the 30- and 60-day crab cultures showed a significant tendency for the survival rate to increase as the density of the shelters increased. However, the effect of the shelters on the survival rate in the 60- and 90-day culture became less clear than in the rearing period of 30 to 60 days.

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