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Effects of water temperature on growth, feeding and molting of juvenile Chinese mitten crab *Eriocheir sinensis*

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ABSTRACT

Chinese mitten crab (*Eriocheir sinensis*) juveniles (0.06–0.15 g) were individually reared at four temperatures (18, 22, ambient temperature and 30 °C) for 35 days. Each treatment (36 replicates per treatment) was conducted in temperature controlled recirculating rearing systems, and the four systems were randomly placed in a room subjected to natural light condition. The food intake, inter-molt period (IP), and molt increment (MI) were determined for each crab. After 35 days, all crabs reared at 18 °C survived, whereas the survival of the other groups was at 97.2%. Animals at 28 and 30 °C grew significantly faster ($P < 0.05$) than those reared at 18 and 22 °C. The first inter-molt period in *E. sinensis* was significantly shortened with increasing temperature ($P < 0.05$). The IP of C5–C8 (the fifth to eighth molting stage started from megalopa) was about 9–18 days. The percentage of MI decreased with body weight, but was not correlated to water temperature. Daily food intake increased notably with temperature and body weight ($P < 0.05$). The percentages of daily food intake in relation to body weight were 2.9%, 3.5%, 5.4% and 5.6% at 18, 22, 28 and 30 °C, respectively. Maximum feed conversion efficiency (FCE) occurred at 22 °C (54.5%), which was significantly higher than that at 28 °C (43.6%) ($P < 0.05$). In conclusion, 28–30 °C is the optimal water temperature for the growth and molting of juvenile Chinese mitten crab.

Statement of relevance: Chinese mitten crab (*Eriocheir sinensis*) is a native crustacean that play an important role in Chinese aquaculture. In general, there is a paucity of research on mitten crab culture technology, especially a dearth in the estimation of technical parameters for effective farming. In addition, there is very little known on the growth characteristics (Inter-molt period and Molt increment) and feeding efficiency of early juvenile stages of *E. sinensis* in relation to temperature. The present study attempts to understand what effects of water temperature on growth, feeding and molting of *E. sinensis*, based on crabs reared individually in a temperature controlled system.

1. Introduction

The Chinese mitten crab *Eriocheir sinensis* (H. Milne-Edwards, 1853) is a native crustacean playing an important role in Chinese crustacean aquaculture. Unlike Penaeid shrimp and freshwater prawn that are produced in large parts of the tropics and sub-tropics, the Chinese mitten crab is only cultured in China (Sui et al., 2011). In recent years, Chinese mitten crab culture has developed rapidly. Mitten crab farming now occurs in all the provinces of China except Tibet, and the total production increased from 4833 metric tons (MT) in 1990 to 796,622 MT in 2014 (FDMA, 2014). The corresponding values of cultured mitten crab were 36,248,000US$ and 5,547,671,000US$ (FAO, 2016), respectively, thereby making it one of the higher priced aquaculture products in China. In view of the economic importance of mitten crab farming to Chinese aquaculture, and the growing trend to adopt mitten crab farming as a relatively more environmentally acceptable culture practice (Wang et al., 2016a, 2016b), a concerted effort has to be made to fine tune the culture practices. In general, there is a paucity of research on mitten crab culture technology, especially a dearth in the estimation of technical parameters for effective farming (Wang and Li, 2010).

Water temperature is generally considered to be one of the major environmental factors affecting survival, molting process, growth and feeding of crustaceans acting either independently or simultaneously with other environmental factors (Anger, 1991; Chen et al., 1996; Hewitt and Duncan, 2001; Hammond et al., 2006; Tarling et al., 2006; Li and Hong, 2007; Jones, 2009; Daoud et al., 2010; Stoner et al., 2010; Gong et al., 2015). Also the inter-molt period and the molting frequency are crucial for growth of crustaceans (Shi et al., 2013). Growth in crustaceans is characterized by a succession of molts (ecdysis) composed of two components, the inter-molt periods (IP) (the interval between successive molts) and the molt increment (MI) (the increase in length/weight that occurs between successive molts), with each of these two

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Table 1
Temperature variations of four treatment groups throughout the experiment. (mean ± SD).

Temperature (°C)	18	22	Ambient (28)	30
Mean ± SD	18.2 ± 0.4	21.9 ± 0.3	27.8 ± 0.7	29.6 ± 0.7
Range	17.5–18.9	21.1–22.5	26.2–29.3	27.9–30.9

phases often exhibiting very different responses to intrinsic and extrinsic factors (Hartnoll, 1982; Li and Hong, 2007). Increased temperature could accelerate growth by shortening the inter-molt period (IP), and/or increasing the molt increment (MI) (Hartnoll, 2001). Hartnoll (2001) reviewed the growth of crustaceans and reported many examples of inverse relationship between inter-molt period and temperature, despite variable with effects of temperature on the molt increment. However, no study of the growth characteristics (IP and MI) and feeding efficiency of early juvenile stages of *E. sinensis* have been conducted in relation to temperature.

Chinese mitten crab is a eurythermic and euryhaline crustacean that can survive in a wide range of temperature, e.g., 1–35 °C (Wang et al., 2007). Zhang and Li (1999) assumed from a field survey that the minimum temperature requirement for molting for the species is 14 °C and they could molt successfully at 35 °C. In a subsequent study, Zhang and Lu (2001) reported that the inter-molt period of juvenile mitten crab from stage five to stage eleven (from megalopa to juvenile crab) is about 15–40 days at a water temperature of 25 °C. Chen et al. (1993) also studied the effect of temperature on growth and feeding rate of juvenile mitten crab. However, findings from this study could be questionable as it was a study on a wild population.

Chinese mitten crab comprises a total of five zoeal and one megalopa stages (Anger, 1991) before entering the juvenile stage. In the present study, Chinese mitten crab were cultured individually from early juvenile stage four (C4, the stage from megalopa to juvenile) at four different temperature regimes for 5 weeks in order to evaluate the role of water temperature (18, 22, ambient temperature, 30 °C) on molting frequency, growth and food consumption. The experiments reported here would assist in understanding the development process of *E. sinensis,* a species of high aquaculture importance to China, the biggest producer of aquaculture in the world, in relation to water temperature. The findings would also serve as a guide to the management and feeding in commercial Chinese mitten crab production practices.

2. Materials and methods

2.1. Experimental design

In the laboratory, four temperature regimes (18 °C, 22 °C, ambient temperature, 30 °C) were chosen and were maintained in a temperature-controlled rearing room. These four temperature regimes are within the range of the temperatures observed in the regions where Chinese mitten crab is farmed (Wang et al., 2007).

Four independent recirculating systems were used for each of the four temperature regimes, and each system consisted of nine cylindrical tanks (Diameter 0.6 × 0.5 m). Each tank was then divided into four equal areas with non-transparent plastic sheets (0.6 × 0.3 m). As a result, there were 36 compartments in every recirculating system with one crab per compartment resulting in 36 replicates for each treatment. Water temperature was measured at 08:00 h and 18:00 h daily. The experiments were conducted in State Key Laboratory of Freshwater Ecology and Biotechnology, Institute of Hydrobiology, Chinese Academy of Sciences for five (5) weeks.

2.2. Culture conditions

Early juvenile mitten crabs were purchased from a commercial crab farm located in Honghu City, Hubei Province, China and transported to the laboratory. All crabs were of stage four megalopa with the average weight of 0.06–0.15 g. Upon arrival, the juvenile crabs were acclimated to room temperature (26 °C) for one week prior to the commencement of the trial. Thereafter crabs were brought up to the experimental temperatures by raising or dropping water temperature at a rate of 2 °C per day, and then maintained for another week at the specific temperature regime. At the beginning of the experiment all the crabs were randomly divided individually into the compartment. Each compartment was fitted with plastic imitation plants, and then, filled with approximately 14-l of recirculating water with a water depth of 20 cm. In a bunch, there were four imitation plants (diameter and length of 3 cm and 35 cm, respectively) fixed on a sinker separately.

The crabs were fed quantificationally and excessively a pelleted commercial crab feed (38% crude protein; 7.58% lipid; 20.09 kJ/g) purchased from Hubei Huize biotechnology company twice daily (08:30 h and 18:30 h, at 1/3 and 2/3 of the total daily ration, respectively). Feeding rate was adjusted at every feeding time based on the assessment of the leftover feed. All leftover feed and feces were removed and mortality and molting were also checked daily before each feeding. Dead crabs and molts were removed during checking. Water was exchanged biweekly. During the experiment, pH was maintained between 8.1 and 8.5, dissolved oxygen (DO) was higher than 5.6 mg/L, and residual chlorine was below 0.05 mg/L. A photoperiod of 12 h light:12 h dark cycle (lighting-up time was 8:30–20:30) was maintained during the experiment and the light intensity was 110.7–280.3 lx (LI-COR Inc. 250A, USA).

2.3. Data collection

The daily feed consumption was calculated by fixed number of pellets provided during feeding and residual pellets that were removed before each feeding. At the beginning and end of the experiment crabs were weighed on an electronic scale (to the nearest 0.01 g) and carapace width measured with a vernier caliper (to the nearest 0.01 mm), crabs were weighed in the morning after 24 h starvation and a wet towel was used to wipe-off surface water before weighing. The process was repeated weekly.

2.4. Statistical analysis

Statistical analyses were performed using SPSS 18.0 and Origin 9.0 was used for plotting. Growth, inter-molt periods, molt increment and

Table 2
Summary statistics (mean ± SD) on growth and feeding related parameters for *E. sinensis* at four rearing temperatures for 35 days. (Mean ± SD) CW: carapace width, SGR: specific growth rates, FCE: feed conversion efficiency.

Temperature (°C)	Initial CW (mm)	Final CW (mm)	Initial weight (g)	Final weight (g)	Survival (%)	SGR(%·d^{-1})	Daily food intake (g·ind^{-1})	FCE (%)
18	6.5 ± 0.53	8.3 ± 0.84[a]	0.10 ± 0.02	0.22 ± 0.07[a]	100.00	2.16 ± 0.83[a]	0.0056 ± 0.0009[a]	45.82 ± 11.74[ab]
22	6.7 ± 0.60	9.5 ± 1.08[b]	0.11 ± 0.02	0.33 ± 0.11[b]	97.20	3.03 ± 1.05[b]	0.0089 ± 0.0014[b]	54.48 ± 10.93[a]
28 (ambient)	6.6 ± 0.45	11.1 ± 1.67[c]	0.11 ± 0.02	0.55 ± 0.26[c]	97.20	4.67 ± 1.21[c]	0.0192 ± 0.0022[c]	43.59 ± 9.64[b]
30	6.7 ± 0.82	11.8 ± 1.68[c]	0.11 ± 0.02	0.67 ± 0.27[c]	97.20	5.15 ± 1.18[c]	0.0225 ± 0.0028[d]	46.47 ± 10.15[ab]

Values with different superscripts in each column are significantly different ($P < 0.05$).
SGR = $[(\ln(W_f) - \ln(W_i)) \times 100] / T$, where W_f is final weight (g), W_i is initial weight (g) and T is experiment time (days).
FCE(%) = $(W_f - W_i) \times 100 / \mathrm{FC}$, where W_f is final weight (g), W_i is initial weight (g) and FC is feed consumption (g).