Eco. Env. & Cons. 25 (July Suppl. Issue) : 2019; pp. (S92-S101)

ISSN 0917–765X

Survival and Growth of mud crab (*Scylla serrata* Forsskål, 1775) reared in crab bucket recirculating aquaculture system

[1]Bambang Yulianto[a], [1]Sunaryo, [1]Nur Taufiq S.P.J., [1]Ali Djunaedi, [1]Subagiyo, [1]Adi Santosa and [2]Agoes Soegianto[b]

[1]Department of Marine Sciences, Diponegoro University, Semarang, Indonesia
[2]Department of Biology, Faculty of Sciences and Technology, Universitas Airlangga, Surabaya, Indonesia

(Received 27 March, 2019; Accepted 30 May, 2019)

ABSTRACT

Mud crab (*Scylla serrata* Forsskål, 1775) is an abundant marine resource in Indonesian waters and has an important economic and nutritional value. Determining the survivability and growth of mud crab *S. serrata* was the aim of this study. This research used the crab bucket recirculating aquaculture system, which is a system of crab aquaculture using some individual buckets, to make every crab bucket independently of feed water and drainage system and function of increases oxygen into the culture water, and can realize automatic drainage of waste and remnant food. Research activities were conducted in the aquaculture laboratory at LPWP (Coastal Area Development Laboratory) Diponegoro University, Jepara, Indonesia. The experimental animal used was mud crabs (*S. serrata*) with the weight from 73 to 87 g. Each crab placed separately in individual crab buckets, where 1 bucket contained 1 individual crab. The crab buckets used were made from plastic material with a diameter and height of 22 x 25 cm respectively, and installed with the recirculating aquaculture system. Two types of culture cages system were applied as a treatment. First, open cages (without bucket lid) were classified in group A; and second, closed cages (with lid bucket) were classified in Group B. Parameter observation was done on the survivability and growth of mud crab. The water quality of culture media was measured and analyzed as a supporting factor. The data were analyzed using variance analysis (ANOVA). The result of the research showed that the survivability of mud crab was between 63 to 79% during 48 days of culture. Absolute growth was between 33 to 76 g (or 0.68 to 1.58 g day^{-1}) after the culture period. The specific growth rate of mud crab ranged from 0.67 to 1.36% day^{-1}. Water quality parameters of culture media by using the recirculating water system were still within the proper range for the life of mud crab. It is concluded that the application of the crab bucket recirculating aquaculture system can give the expectation for the development of mud crab culture in the future.

Keywords: *Crab Aquaculture, Scylla serrata, Recirculating Aquaculture System, Individual Cage, Water Quality, Growth*

Introduction

Mud crab (*Scylla serrata* Forsskål, 1775) is one of the largest portunids living on the coast and mangrove swamps and vast distributed throughout the Indo-Pacific coastal region (Barnes *et al.*, 2002; Le Vay *et al.*, 2007; Shelley and Lovatelli, 2011). They associate with mangrove forests inundated with full salinity oceanic water for the greater part of the year but can tolerate reduced salinity (Keenan *et al.*, 1998; Shelley

Corresponding author's email: [a]bambang.yulianto@live.undip.ac.id; [b]agoes_soegianto@unair.ac.id

and Lovatelli, 2011). This crab has high economic and nutritional value and marketed in various forms of production, such as live crab, soft shell crabs, crab meat, crab paste, crab cakes, crab claws and crab waste that can be processed into various raw materials of the pharmaceutical industry, fisheries (Edwards and Early, 1969, Galetti, 2010). They have characteristics quality meat, large size, and soft taste, hence there is a lot of demand and high prices in domestic and international markets (Azra & Ikhwanuddin 2016).

In Indonesia, due to its delicacy and greater size, larger market demand and higher prices, resulting in a wide development in the mud crab *S. serrata* commerce with greater scope in the domestic market, such as in Kalimantan (East Kalimantan, South Kalimantan, North Kalimantan), Sulawesi (South Sulawesi, Southeast Sulawesi, Central Sulawesi), Java (Subang, Indramayu, Cilacap, Pemalang, Gresik, Sidoarjo), Sumatra (Riau, Jambi, North Sumatra, Lampung), Papua, West Papua and others, and as well as in the export market (including Japan, Hong Kong, South Korea, Taiwan, Singapore, Malaysia, Australia and France) (Sulistiono *et al.,* 2016).

Southeast Asian fishers have been cultivating mud crabs for a long time, which were based on young crabs taken from capturing in nature, and fattened by operating culture in an existing pond or pen, a tidal river or creek (Begum *et al.,* 2009; Shelley, 2011; Petersen *et al.,* 2013; Dos Santos Tavares *et al.,* 2017; Fatihah *et al.,* 2017). As fishers have done so far, the culture of crabs in ponds shows some disadvantages, such as: requiring large area, exposure to pollution from open waters, high penetration of sunlight to crabs, cannibalism, crabs escaped from ponds still high, burrowing habit causing difficult harvest, low security, and wasteful energy (Datta *et al.,* 1999). Several commercial cultures of mud crabs have been carried out but low survival has become a major obstacle for commercial operations. The major cause of mortality in *S. serrata* due to they are maintained in communal rearing ponds or tanks (Genodepa *et al.,* 2004; Holme *et al.,* 2007). In crab culture with the communal rearing ponds method, intraspecific predation is an important source of mortality, such as *Macrobrachium rosembergii, Homarus americanus, Cancer master, Cancer pagurus, Porcellana platycheles* and *Paralithodes camtschaticus* (Sastry and Zeitlin-Hale, 1977; Mortensen and Damsgard, 1995; Nair *et al.,* 1999; Amaral *et al.,* 2009; Daly *et al.,* 2009). Hence, cannibalism is one of the main reasons for failures in the development of culturing methods for a variety of crab species (Zmora *et al.,* 2005; Ventura *et al.,* 2008; Sotelano *et al.,* 2012). By maintaining mud crabs in individual containers, the survival of mud crabs can be dramatically improved compared to crabs which are maintained in ponds where cannibalism is prevalent (Shelley and Lovatelli, 2011).

The improvement or innovation of the crab culture system through the crab farming technology in battery boxes immersed in the pond still shows some weaknesses, such as high mortality rate, decreased water quality due to significant remnant food and exposed to pollution from open waters, crab exposed by direct sunlight resulting in high mortality, bad water recirculation system, low land efficiency, low-security level, and low work comfort (Sunaryo *et al*., 2007; Begum *et al*., 2009). Then, there is necessary to introduce an advanced system in crab culture by operating the flow or recirculation of land-based cultivation facilities (Shelley and Lovatelli, 2011). The crab bucket recirculating water aquaculture system is an advanced system which provides individually aquaculture cage for each crab to avoid the crabs between the mutual killing. The system is equipped with a recirculating water system passing a water filter to purify and increase oxygen into water media. This aquaculture recirculation systems are a necessary tool to provide sustainable and continuous aquaculture production with low environmental impact. This system can automatically discharge feces and remnant food to maintain a good quality water environment in each bucket. This aquaculture system is very useful in supporting the development of crab aquaculture and has a positive impact on improving marine agro-industry, especially mud crab aquaculture in Indonesia.

This study aimed to determine the survivability and growth of mangrove crabs which cultivated in the crab bucket recirculating aquaculture system. The result of the research is expected to be new information on a more efficient, ecological, household scale crab cultivation system which can solve the problem of traditional crab cultivation.

Materials and Methods

The research was conducted directly in the aquaculture laboratory at LPWP (Coastal Area Development Laboratory) Diponegoro University, Jepara, Indonesia from September to November 2016. The water quality analysis was conducted in the Laboratory of the Faculty of Fisheries and Marine Sciences, Diponegoro University and the Laboratory of the Center for Development of Brackish Aquaculture at Jepara.

Test material

The test material was a unit of crab bucket recirculating aquaculture system (Figure 1 and 2).

Experimental animals

Experimental animals used in this research were adult stadia of mud crabs (*S. serrata*), with initial weight ranged from 72.83 to 86.88 g and carapace length ranged from 7 to 11.1 cm. All crabs were captured from nature and then preserved under culture conditions. Totally, about 192 male and female crabs were used in the present study, and only active and intermoult crabs were selected and used as experimental animals.

Treatment and research design

This research used an experimental design with the principle of replication (Kothari, 2004). The variables used were independent variables in the form of open buckets (without bucket lid) (the group of bucket A) and closed buckets (with lid bucket) (the group of bucket B) (Figure 2b), and dependent variables were crab survivability and crab growth. Each treatment was replicated 4 times (A1, A2, A3, A4, and B1, B2, B3, B4). Each group of bucket consisted of 24 experimental units of the bucket, where each bucket consisted of 1 crab individual.

Buckets and water media

Crabs were reared in a crab bucket recirculating aquaculture system (Figures 1 and 2) to make every crab live independently, and receive clean water with high oxygen from a recirculating drainage system, which can realize automatic disposal of waste and remnant food. It consisted of the series of culture buckets, with clean water circulation entry toward each bucket as water culture supply. The residual wastewater culture collected in the container and pumped to the water filter to be cleaned, and then recirculated towards each bucket. Hence, this system always maintains good water quality and a comfortable environment. Buckets (volume of 8.6 l) were set on four layers, but this study used only two lowest layers. The first bottom layer was the group of buckets A (A1, A2, A3, A4) (without bucket lid), followed by the group of buckets B (B1, B2, B3, B4) (with bucket lid) in the second bottom layer. Each bucket group was composed of 24 buckets (for example $A1_{-1}$, $A1_{-2}$, $A1_{-3}$,…$A1_{-24}$) and all bucket groups amount to 192 buckets. Each bucket contained one crab to prevent from killing each other and gets clean water supply from water distribution pipes coming from the water filter. Culture media used seawater, previously filtered using sand filters and sanitized with 125 mg L^{-1} chlorine solution (Leblanc & Overstreet 1991). Animals were maintained at a salinity of 10-15‰, water temperature between 26 and 30° C, pH 6.5-8.2, oxygen > 5 mg L^{-1}, light intensity was 12 hours dark and 12 hours light.

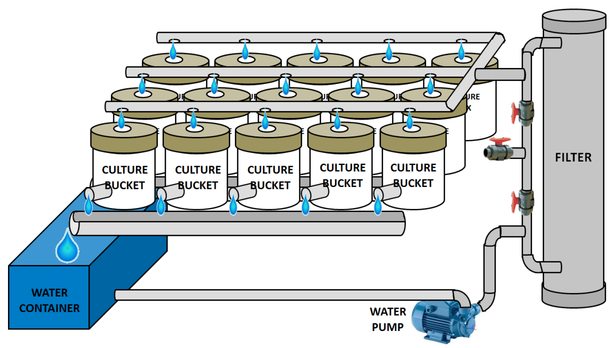


Fig. 1. The design of the crab bucket recirculating aquaculture system

Every day crab molting and survival were observed and recorded in order to calculate survival rate (SR). Crabs are weighed every 3 days to determine their growth. The survival rate of crabs was examined based on Jobling (1995),

$$SR\ (\%) = \frac{N_t}{N_0} x100$$

Where SR is survival of crab (%), No is the number of crabs at the beginning of the study (tail), Nt is the number of live crabs at the end of the study. Growth performance of the crabs in terms of absolute growth rate (AGR) (g day^{-1}) and specific growth rate (SGR) (% day^{-1}) was determined over time. These were calculated based on body weight using the formula below:

$$\text{Absolute Growth Rate (AGR)} = \frac{W_2 - W_1}{t}$$

$$\text{Specific Growth Rate (SGR)} = \frac{\ln W_2 - \ln W_1}{t} x100\%$$

Where W_1 is the initial weight (g), W_2 is the final weight (g), t is the length of culture (day), SGR is the daily growth rate (% day^{-1}), and ln = natural logarithm (Jobling, 1995).

Feeding

The experimental crabs were fed three times a day (06.00; 17.00, and 23.00) at 10% wet body weight using trash fish obtained directly at the fish auction around the study site.

Water quality

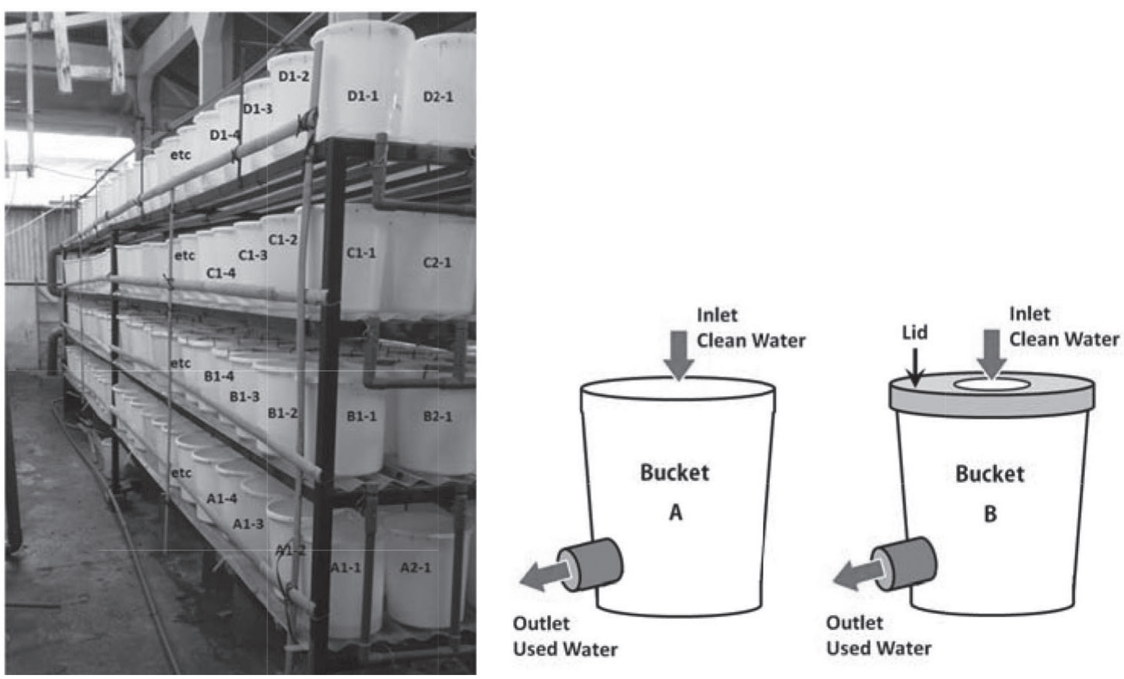
Water quality parameters namely dissolved oxygen, salinity, pH, temperature of culture media were monitored at each sampling period and were measured using DO meter (Eutech Model DO6+, Singapore), a Portable Refractometer (Rhb -82 Atc Brix 0-32%, China), pH meter (pH Tester 10, Singapore), and a mercury thermometer, respectively. Ammonia, nitrite, and nitrate were analyzed using Spectrophotometer. Water quality observations were undertaken at the early period of the study and every three days during the culture period when weighing the crabs.

Data analysis

The data taken include survivor crab, absolute growth, and specific growth rate (Takeuchi 1988). While supporting parameter is the number of molting, the water quality of culture media including temperature, salinity, pH, dissolved oxygen, and ammonia, nitrite and nitrate. Measurements of crab weight and water quality parameters were taken every six days. Data obtained from observation parameters during the study were analyzed statistically. ANOVA was done to observe any differences in growth parameters of crabs.

Results and Discussion

Mud crab survival occurred during the study is shown in Figure 3. Overall, the survival of the mud crab maintained with the crab bucket recirculation aquaculture system showed a high survival rate (75 - 79%, or about 0.48% mortality per day) for crabs cultured in group of bucket B (bucket with lid), and enough high (63 - 67%, or about 0.72% mortality per day) for crabs cultured in group of bucket B (bucket without lid) for 48 days of culture. The highest survival rate (79.17%) occurred in mud crabs reared in bucket groups of B4, followed by group B1, B2, and B3 (75%), and slightly lower (67%) in crab reared in bucket group of A1 and A2. And the lowest survivability (63%) occurred on crabs kept in bucket groups of A3 and A4. Higher survivability occurred



(a) (b)

Fig. 2. a) The setting of crab buckets recirculating aquaculture system; b) Bucket A (without lid) and Bucket B (with lid)

in bucket treatment with lid (the group of bucket B) than treatment bucket without lid (the group of bucket A). A high survival rate was also found in mud crabs reared in cages with shelter (59.26%) compared with the pens without shelter (20.37%) (Fatiha *et al.,* 2017). In this study bucket with lid could serve as a cage with a shelter for crabs to able to hide behind the bucket lid.

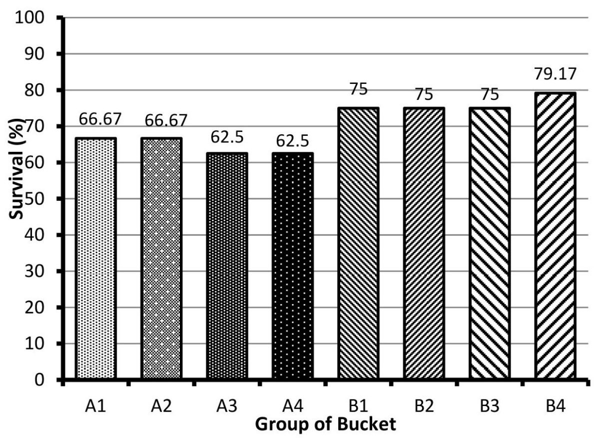


Fig. 3. Survival rate (%) of mud crab *S. serrata* reared in crab bucket recirculating aquaculture system during 48 days.

Mud crab survival in this study was higher than that mud crab (*S. tranquebarica*) in grow-out culture at Kakinada coast India, which only reached 45% during 45 days of culture (1.22% mortality per day) (Pedapoli & Ramudu 2014), and mud crab (*S. serrata*) cultured in drive-in cages which had 53% of survival rate (47% mortality in 90 days culture, or 0.52% mortality per day) and in pens which attained only 31% of survival rate (69% mortality in 90 days culture, or 0.76% per day) (David 2009). But it was lower than the survival rate of mud crab *S. serrata* fattening during 12-16 days in bamboo cages partitioned into 16 compartments and encircled earthen brackishwater pond, which reached 93.75% and 86.12%, respectively (Begum *et al.,* 2009), and the survival value of mud crab cultivated in mangrove area which ranged from 86.67-93.33% (Karim *et al.,* 2017). Several factors are responsible for the decrease in mud crab survival, from environmental media until crab culture systems. The sudden drop in survival rates has been noticed from 87% to 45% when salinity has been decreased from 29.6 ppt to 10.4ppt in between 30th day to 45th day (Pedapoli & Ramudu 2014). The crab culture method is suspected to be one of factor declining survival rate of mud crabs. Communal culture systems make crabs interact together in sharing culture community creating a threat to the lower survival rate of crabs due to the cannibalistic nature of mud crabs (Liong, 1992; Pedapoli and Ramudu 2014). Death rates from cannibalism have been recorded (Iversen 1986; Borisov *et al.,* 2007; Sotelano *et al.,* 2012). The culture system of the battery bamboo cage (individual mud crab per compartment) method records 87% survival (DA, Region VI, 1988), and 80-100% after 35 days of mud crab culture (Kuntiyo, 1992). The survival rate of crab was found 93.75% in individual cages, but it declined to 86,12% when the culture method in the encircled earthen pond (Begum *et al.,* 2010). Escritor (1972) stated that cannibalism in *S. serrata* must be controlled through a habitat system that is safe from mutual killing; whereas survival in pond culture is generally lower as a result of cannibalism and escape (Liong, 1992). Cannibalistic nature of mud crabs is a reason for poor survival. Therefore the safety of crab must be taken to reduce cannibalistic nature by using hiding pots placed in the pond as a shelter that can cover the molting crab from the other animal (Pedapoli and Ramudu, 2014). The effect of an individual culture using a semi-open recirculation system on juvenile of majid crab *Maja brachydactyla* showed a high survival during the whole experiment (Guerao and Rotllant 2009). By holding mud crabs in individual containers, as in fattening operations, the survival rate can be dramatically improved compared with pond-reared crabs where cannibalism is prevalent (Shelley and Lovatelli, 2011).

Absolute crab growth during the study period (48 days) showed a varied increase (Figure 4). The average initial weight (at d-0) of crabs ranged from 72.83 g to 86.88 g. The absolute growth of the crabs after the period of culture ranged from 32.82 to 76.05 g. In the group of A4, the initial weight was about 86.25 g and increased to about 119.07 g after 48 days of culture. Crab weight gained 32.82 g in bucket group A1, and it was expressed the crab group with the lowest absolute growth. The crab settled in bucket group of B4 became the group of crabs with the largest weight gain, compared to other bucket groups. The initial weight of crab from group B4 was about 82.38 g. After the culture period, the crab weight increased to 158.42 g, resulting in weight gain of 76.05 g. Crab reared in cages with lid (B1, B2, B3, and B4) showed the absolute growth (45.74-76.05 g) which was higher than the cages without lid (A1, A2, A3, and A4) (32.82-52.09 g). The difference in weight gain was statistically ($p<0.05$) significant. The result of this research was relatively comparable with mud crabs (*Scylla olivacea*) cultured in mangrove area in South Sulawesi, Indonesia, where their growth reached from 27 to 50 g after 150 days of culture (Karim et al., 2017).

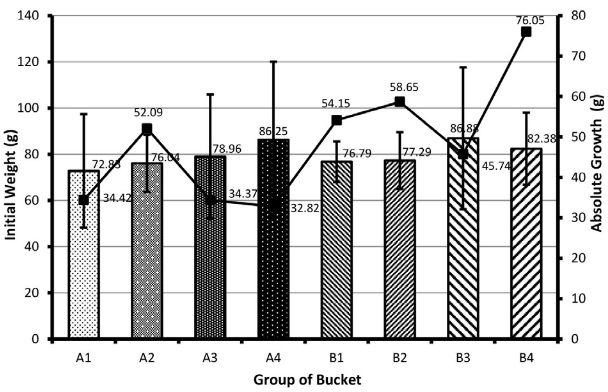


Fig. 4. Initial weight (g) and absolute growth (g) of mud crab (*S. serrata*) reared in crab bucket recirculating water aquaculture system during 48 days.

Absolute growth rates of mud crab (*S. serrata*) reared in culture buckets without lid (A1, A2, A3, A4) were relatively lower than that were cultured in buckets with lid (B1, B2, B3, B4) (Figure 5). The average absolute growth rate of bucket A was 0.80±0.19 g day^{-1} and bucket B was 1.22±0.27 g day^{-1}. The lowest growth rate was found in the group of bucket A4 (0.68 g/day) and the highest was the group B4 (1.58 g/day). The absolute growth rate of the mud crabs in this study varied relatively compared to the growth rate of mud crab resulted from several other researchers. It was relatively comparable with mud crabs drived-in cages in north coast Kenya, where their growth reached 1.25 g day^{-1} (David, 2009), while it was higher than in the study of Suprapto *et al.* (2014) that the mud crabs cultured in bulk with trash fish fed resulting in 0.8 g day^{-1} of growth rate. Meanwhile, mud crabs had higher average body weight (0.82 g day^{-1}) compared with unfed crabs (0.61 g day^{-1}) regardless of whether chelipeds were intact or trimmed (Quinitio and Estepa, 2011). The average daily growth rate of mud crab (*S. tranquebarica*) was noted throughout the experimental period in average 2 g day^{-1} (Pedapoli and Ramudu, 2014), hence, these crabs showed higher daily growth compared to this study.

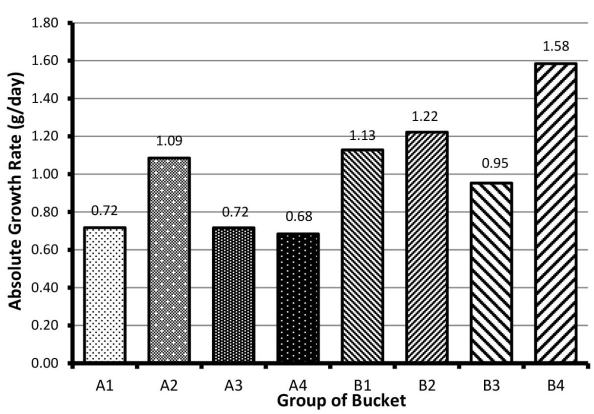


Fig. 5. Absolute Growth Rate (g day^{-1}) of mud crab (*S. serrata*) reared in crab bucket recirculation water aquaculture system during 48 days

In general, mud crabs cultured in group A (open cages) have lower SGR than group B (closed cages) (Figure 6). The SGR mud crabs cultured in group A (open cages) ranged from 0.67±0.13% day^{-1} to 1.09±0.18% day^{-1}. Otherwise, the SGR in group B (closed cages) started from 0.88±0.22% to 1.36±0.18% day^{-1}. SGR values were higher in the group of crab cultured on the closed bucket (B1, B2, B3, and B4) compared crab reared in open bucket (A1, A2, A3, and A4). These SGR between the groups was different significantly ($P<0.05$). The SGR of mud crab juveniles after 50 days of experiment was recorded significantly ($p <0.05$) higher in the cage with shelter treatment (5.07±0.05% day^{-1}) compared to the cage without shelter (4.10±0.07% day^{-1}) (Fatihah *et al.*, 2017). In this study treatment B (closed bucket/bucket with lid) demonstrated its function as a cage with shelter, while treatment A

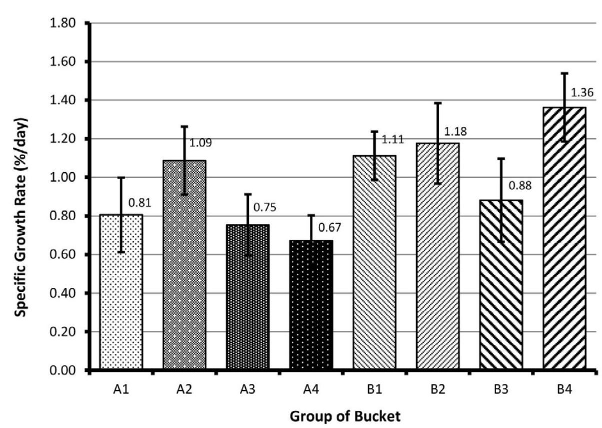


Fig. 6. Specific growth rate (%) of mud crab (*S. serrata*) reared in crab bucket recirculating aquaculture system during 48 days of culture. Group of the bucket of A (A1, A2, A3, and A4) was the buckets treated without bucket lid and B (B1, B2, B3, and B4) the buckets treated with bucket lid.

(closed bucket/bucket without lid) is a cage without shelter. Hence, this study is consistent with the results Fatiha *et al.* (2017). Several other researchers got results that the SGR of mud crabs was lower compared to this study, such as Agus (2008), who showed that mud crabs maintained in a brackish pond for 18-19 days grew 0.58% of body weight day^{-1}. Sayuti (2012) showed that mud crabs maintained for 24 days in a brackish pond grew in the range of 10-13% (or 0.41-0.54% body weight day^{-1}). The growth of mud crabs in brackish ponds and fed with trash fish produced 0.82% body weight day^{-1} of growth (Sunaryo *et al.* 2007). David (2009) stated that drive-in mud crab cages recorded a significantly better growth rate (1.25±0.42% day^{-1}) compared to pens (0.68±0.24% day^{-1}). The daily growth rate obtained from mud crab cultured in mangrove area in South Sulawesi, Indonesia ranged from 0.67 to 1.20% day^{-1} (Karim et al., 2017).

In crabs, growth spikes in body weight and carapace size generally occurs during the aftermath of molting. In this study, a significant boom in body weight after molting crab growth ranged from 47.47 to 90% compared to the initial weight of the crab (Figure 7). The specific growth rate of the mud crab in the present study was correlated to the number of molting. The higher the molting number, the specific growth rates increased.

Catacutan (2002) stated on their work on *S. serrata* that average weight of mud crab after having three times molting reached 75.8 g, while the initial weight was 11.18 g. It means that a newly molted crab almost doubles (100%) its body size and weight due to water content (Catacutan 2002; Chen & Chia 1997). The results of some researches showed that crabs have a certain growth pattern, and weight growth is not always followed by growth in length and width of the carapace, because they cannot grow in a linear fashion like most animals and they have a hard outer shell (the exoskeleton) that does not grow, they must shed their shells (called molting) (Steven, 2007). Just as we outgrow our clothing, crabs outgrow their shells. Length and width growth of carapace of mud crab occurs during molting while molting frequency in mud crab occurs 15-20 times during its life (Shelley and Lovatelli, 2011; Steven, 2007). Due to the weight growth of mud crabs during intermolt is greatly limited by the size of the carapace, the maximum growth range is greatly limited by the size of the carapace at that time.

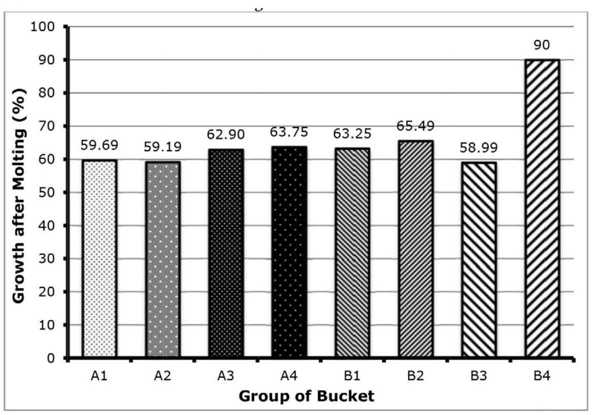


Fig. 7. Average percentage (%) of growth of mud crab *S. serrata* after molting reared in crab bucket recirculating aquaculture system during 48 days compared initial weight.

Water quality parameters of culture media in this study were still in the proper range for the mud crab life. The water temperature of culture media ranged from 26 to 29 °C in the culture bucket, and between 27 and 30 °C in the reservoir; pH was 7-8; salinity was 15-32%; NH_3-N was 0.039-0.041 mg L^{-1}; NO_2-N was 0.359-0.374 mg L^{-1}, and dissolved O_2 was > 5 mg L^{-1}. The results of various studies indicated that the optimal growth for *S. serrata* was at a temperature of 30 °C, with good growth from 25 to 35 °C (Shelley and Lovatelli 2011), 26-32 °C (Aslamsyah and Fujaya 2010), 26.3-30.3°C (Herlinah *et al.,* 2016); salinity 10-25‰ (Shelley and Lovatelli 2011), 15-30‰ (Aslamsyah and Fujaya, 2010), 29-33‰ (Herlinah et al 2016); pH 7.5-8.5 (Shelley and Lovatelli 2011), 7.1-8.5 (Herlinah *et al.,* 2016); dissolved oxygen was > 5 mg L^{-1} (Shelley and Lovatelli 2011), 3.1-5 mg L^{-1} (Agus 2008), 2.5-3.61 mg L^{-1} (Herlinah *et al.,* 2016).

Conclusions

The lowest crab survivability (SR) during 48 days of culture was 62.50%, and the highest was 79.17%. The absolute growth (AG) achieved during the maintenance period of mud crabs was 32.82 g (or 0.68 g day^{-1}) the lowest, and the highest was 76.05 (or 1.58 g day^{-1}) g for 48 days culture period. The specific growth rate attained 0.67% day^{-1} (the lowest) and 1.36% day^{-1} (the highest). The SR, AG, AGR, and SGR were higher in the crabs cultured in the cage with the lid (close bucket) than in the cage without lid (open bucket). Water quality parameters of mud crab culture media by using the crab bucket recirculating aquaculture system was still in the proper range for the life of mud crabs. The application of crab bucket recirculating aquaculture system can give the expectation for the development of mud crab culture, because it can provide assurance of better-controlled water quality, better crab safety (from cannibalism and escape from the cage), high crab survivability, high crab growth, save seawater, the comfort of employees in the production process, as well as resource efficiency.

Acknowledgments

The authors would like to thank for grants PNBP 2016 (non-tax revenues) from Diponegoro University, channeled through LPPM (Institute for Research and Community Services) Diponegoro University for the implementation of this research.

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