The effect of recirculating aquaculture system on blue swimming crab (*Portunus pelagicus* Linnaeus, 1758) instar crablet growth and survival rate

[1]Yushinta Fujaya, [1]Haryati, [1]Sriwulan, [1]Besse T. Nurkamilah, [1]Muawwana, [2]Muhammad Niswar

[1] Fisheries Department, Faculty of Marine Science and Fisheries, Hasanuddin University, Tamalanrea, Makassar, Indonesia; [2] Department of Informatics, Faculty of Engineering, Hasanuddin University, South Sulawesi, Indonesia. Corresponding author: Y. Fujaya, yushinta.fmuskar@gmail.com; yushinta.fujaya@unhas.ac.id

Abstract. The purpose of this study was to investigate the effect of Recirculating Aquaculture Systems (RAS) on the growth and survival of blue swimming crab (*Portunus pelagicus*) seed (instar crablets). The study was carried out at the Universitas Hasanuddin Crab Hatchery in Bojo Village, Barru Regency, South Sulawesi, Indonesia from March to July 2020. Two nursery systems were tested, namely RAS and NON RAS installations. Five day old crablets (N = 400) were stocked at a density of 100 crablets per tub. Crablets were maintained for 1 month. The results showed that maintenance using RAS installations resulted in significantly faster crablet growth (weight gain, increase in carapace width and carapace length) than NON RAS ($p < 0.05$). However, crablet survival rate did not differ significantly between the two installations. Crablet growth was strongly influenced by water quality. Although the measured values of water quality parameters such as temperature, salinity, and pH did not differ between the two maintenance installations, the ammonia and nitrite content in the NON RAS installation were higher than in the RAS installation.

Key Words: crablet, growth, *Portunus pelagicus*, recirculating aquaculture system, survival rate, water quality.

Introduction. The blue swimming crab (*Portunus pelagicus*) is a marine crab that is widely distributed in Indonesian waters and has become an important fishery commodity. However, in recent years, both the blue swimming crab and mud crabs (*Scylla* sp.) have been declared threatened with extinction in Indonesian marine waters, so that the Government of the Republic of Indonesia has limited the catch of these animals and recommended cultivating these species (KKP 2015). Currently, crab aquaculture still mainly uses wild-caught seed with only a small portion of seed sourced from hatcheries. Of course, this type of culture still contributes to increased overexploitation. According to Shelley (2008), in some countries the uncontrolled fishing of juvenile crabs for aquaculture has led to recruitment overfishing, even though crabs are very fecund and have extended spawning seasons over much of their range.

The threat to wild *P. pelagicus* populations and the increasing interest in cultivating this species has prompted researchers to develop seed production technology (Ravi & Manisseri 2012; Azra & Ikhwanuddin 2015; Trijuno et al 2015). Soft shell crab culture is one aquaculture activity that requires a lot of juvenile crabs. Therefore, during the last few years, substantial progress has been made in developing methods for intense juvenile crab production (Ikhwanuddin et al 2012; Fujaya et al 2016; Chakraborty 2018). However, up to the present time, slow growth and high mortality rates are still a problem in crab seed production.

Optimal water quality is needed to support the health, growth and survival rate of crab seed. Recirculating Aquaculture Systems (RAS) are one technological option that has become increasingly widely used for intensive aquaculture activities in recent years. In addition to minimizing water use and improving biosecurity (Murray et al 2014), RAS technology can be used to control several important water quality parameters such as dissolved oxygen, carbon dioxide, ammonia, nitrites, nitrates, pH, salinity, and suspended solids. This allows the maintenance of good conditions for growth and optimal feed utilization, making RAS aquaculture economically profitable (Appiah-Kubi 2012). Therefore, this study was conducted with the aim of investigating the effect of using RAS on water quality, and the growth and survival rate of blue swimming crab seed (instar crablets).

Material and Method

Study sites. This study was conducted from March to July 2020 at Hasanuddin University Crab Hatchery, Bojo Village, Barru Regency, South Sulawesi, Indonesia. Water quality parameters were measured at the Water Quality Laboratory, Faculty of Marine Science and Fisheries, Hasanuddin University.

Recirculating system. The recirculating system was aimed at maintaining optimal conditions for crab culture by reducing the accumulation of faeces and feed residues in the rearing containers. Three different filters were used i.e. biological, chemical, and physical. The physical filter consisted of cotton, green stone, and sand layers, while the chemical filter was made of zeolith stones, active carbon, silica sand. Carbon and silica sand function to purify the water by filtering out the remaining impurities of the feed and removing odours. Bio balls were used as biological filters. The bio ball is a place for decomposing bacteria to live. The RAS installations were also equipped with UV to kill pathogenic bacteria that remained in the water before it was dispensed into the culture tank.

Experimental design and setup. This study used 400 *P. pelagicus* instar crablets aged 5 days at the beginning of the experimental period. The crablets were stocked at a density of 100 crablets/800 L culture tank containing treated water. The oxygen solubility of the experimental media was maintained by complete aeration in each culture tank. Two replicates were prepared for each treatment. There were two treatments, namely: rearing crablets in RAS culture tanks and NON RAS culture tanks. In the NON RAS culture tanks, the water did not flow through a recirculation system; instead, the water was changed manually (20% replacement every 2 days). The experiment was terminated after a four week culture period.

The crablets were given artificial feed and trash fish at a dose of 3 mg L^{-1} every day. The feeding frequency was four times a day, at 06.00 AM, 09.00 AM, 01.00 PM, and 09.00 PM. Water quality parameters such as temperature, salinity, pH, and dissolved oxygen were recorded daily *in situ*; hardness, alkalinity, ammonia, nitrates, nitrites, sulphate, phosphate, and iron were measured only at the start and end of the study.

Data and statistical analysis. Growth was estimated once a week by taking a sample of 10 crablets from each treatment. The crablets were weighed using an analytical balance with a precision of 0.01 g. Carapace width and length were measured using a ruler with 0.5 mm precision.

The mean wet body weights (BW) for each treatment were used to calculate the specific growth rate (SGR), according to the following formula: SGR = (Wt - W0) / t x 100 where SGR is specific growth rate (% day^{-1}); W0 is initial body weight (g), Wt is final body weight (g); t is culture period (days). The survival rate (%) at a particular time was calculated as the number of live crabs divided by the initial number of crabs in each replicate.

In this experiment, the data collected were analysed using SPSS for Windows version 16.0. The Student's T test was used to determine whether there was a significant difference between treatments. All results were presented as means ± standard error. Differences was considered to be statistically significant when $p < 0.05$.

Results

Growth. There was a significant difference ($p < 0.05$; Table 1) in absolute growth in terms of crablet carapace length and width between the RAS and NON RAS installations after one month of maintenance. The weekly growth charts showed that significant growth occurred after week 2 in all three growth parameters measured (Figures 1 and 2).

Table 1

Absolute growth and specific growth rate of crablets (mean±standard error)

Culture systems	*Absolute growth*			*SGR (% day^{-1})*		
	Carapace length (cm)	*Carapace width (cm)*	*Weight (g)*	*Carapace length*	*Carapace width*	*Weight*
RAS	1.32±0.24	2.56±0.60	1.64±0.77	4.40±0.81	8.53±2.01	5.48±2.57
NON RAS	0.98±0.26	1.88±0.52	1.15±0.62	3.25±0.85	6.25±1.72	3.83±2.06

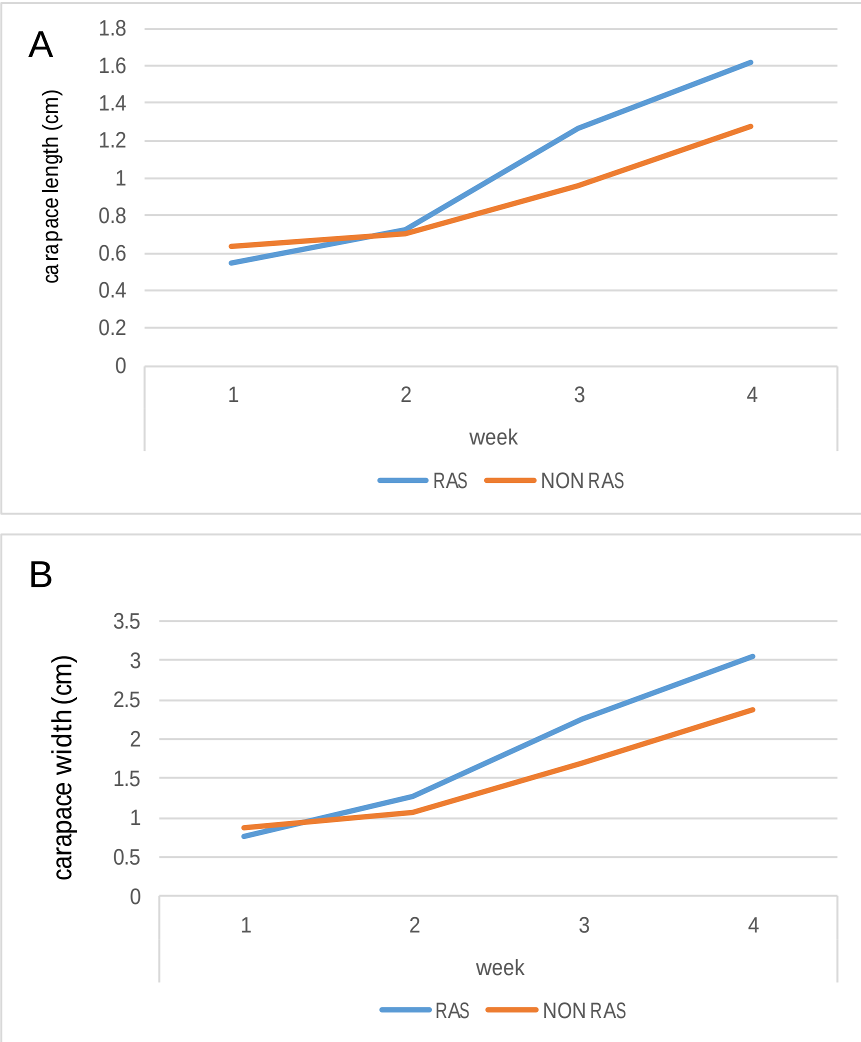

Figure 1. Change in *Portunus pelagicus* instar crablet carapace length (A) and width (B) during culture.

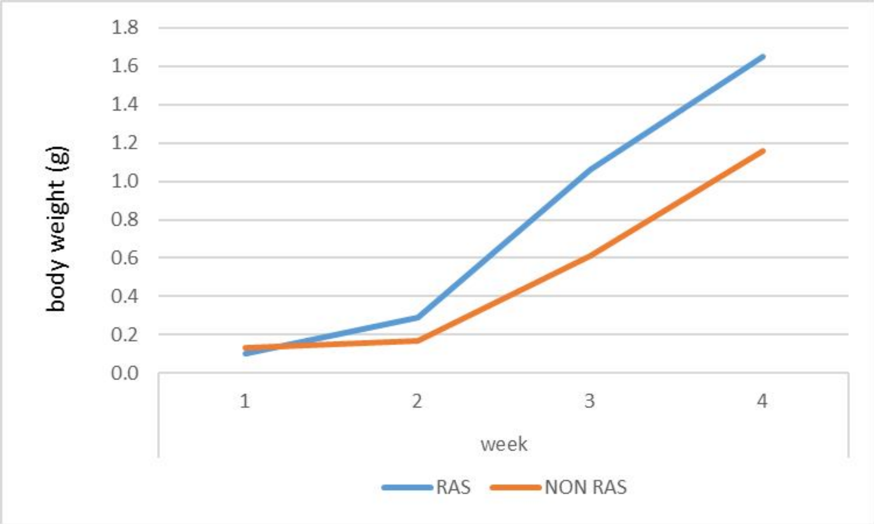

Figure 2. Change in *Portunus pelagicus* instar crablet body weight during culture.

Survival rate. Survival rate of the *P. pelagicus* crablets was similar in the tanks with and without a recirculation system, being 43.5% in the RAS and 43% in the NON RAS tanks (Table 2). The highest mortality occurred in the first week, decreasing during week 2 but increasing again in the third and fourth weeks.

Table 2

Survival rate (%) of crablets (mean±standard error) every week of rearing

Culture systems	*Weeks*			
	1	*2*	*3*	*4*
RAS	67.0±1.41	62.0±1.41	55.0±1.41	43.5±7.78
NON RAS	68.0±4.24	63.5±4.95	54.0±9.90	43.0±7.07

Water quality. The detailed water quality analysis of initial and final water quality parameters (Table 3) showed significant differences between RAS and NON RAS tanks for several parameters. These were: hardness, alkalinity, ammonia, nitrate, nitrite, sulphate, phosphate, and iron.

Table 3

Water quality parameters in the RAS and NON RAS tanks

No.	*Parameter*	*Unit*	*Beginning of the research*	*End of the research*	
				RAS	*NON RAS*
1	Total hardness	ppm	654.65	686.69	570.57
2	Calcium hardness (Ca)	ppm	240.24	248.25	258.26
3	Magnesium hardness (Mg)	ppm	414.41	438.44	312.31
4	Alkalinity	ppm	116.0	116.0	116.0
5	Ammonia (NH_3)	ppm	0.025	0.012	0.016
6	Nitrate (NO_3)	ppm	0.592	1.873	2.184
7	Nitrite (NO_2)	ppm	0.546	0.791	0.461
8	Sulphate (SO_4)	ppm	732.9	660.9	780.2
9	Phosphate (PO_4)	ppm	4.168	4.223	4.441
10	Iron (Fe)	ppm	0.43	1.55	1.12

The daily water quality observations showed similar values in the two systems. Water temperature in the two culture tank types ranged from 26 to 30^{o}C, and salinity was in the range 30-34 ppt. The pH in RAS tanks was in the range 7.7-8.1 while the range in NON-

RAS tanks was 7.4-8.0. Dissolved oxygen (DO) in the RAS tanks ranged from 5.0 to 7.0 ppm, while in the NON RAS tanks DO ranged from 4.9 to 6.7 ppm.

Discussion. The results of this study indicate that RAS can reduce the concentration of several harmful compounds in the water so that the culture medium can better support the growth of the cultured organisms. The rate of crablet weight gain was 44% faster in RAS than NON RAS tanks. Likewise, the growth rate in carapace size was 36% faster in RAS than in NON RAS tanks. The faster growth rate in the RAS tanks is thought to be due to the better water quality. Hastuti et al (2017) argued that recirculation is one of the cultivation systems for the production of aquaculture commodities with a system to control environmental and safety factors.

In this study, it appears that remains of feed and faeces were found in NON RAS tanks. In contrast, in the RAS tank, much less remaining feed was left in the tanks. Tanks with the RAS system had clear water due to the process of filtering dirt in the RAS system while in NON RAS tanks the water remained cloudy because dirt remained at the bottom of the tank. This is because in the RAS tank, the cultivation water continues to flow at a rate of 5 L per minute. The flowing water is then cleaned by flowing through the RAS filtration system. Similar to this study, when using RAS for *Litopenaeus vannamei* culture, it was found that the increased recirculation rate could improve the water quality and promote the growth of shrimp (Chen et al 2019). However, the survival rate and yield of *L. vannamei* were higher under a relatively low water recirculation rate.

RAS which is equipped with appropriate filtration as in this study can help maintain optimal water quality. The better water conditions in the recirculation tanks enable the crablets to grow well. In this study, physical, the chemical and biological filters used successfully controlled ammonia. Silica sand removed small particles of feed waste and crab faeces from the water and Bio balls functioned as a habitat for bacteria which decompose ammonia. Ammonia is a toxic compound which is a source of breakdown of organic nitrogen (protein and urea) and inorganic nitrogen by microbes and fungi found in soil and water, which comes from the decomposition of organic matter (metabolic waste, feed residue). Björnsson & Ólafsdóttir (2006) suggest that, in recirculation systems at high stocking densities, ammonia (the main end product of nitrogen metabolism in teleost fish) can reach toxic levels (acute or chronic), unless this system is equipped with an efficient bio filter with bacteria that can break down ammonia into the less toxic nitrite (NO_2) and nitrate (NO_3) compounds. In another study, total ammonia nitrogen (TAN) did not correlate with crablet survival, but the nitrate and nitrite nitrogen concentrations had a highly significant effect (Boonyapakdee & Bhujel 2019). In this study, both the ammonia and nitrate content were higher in the NON RAS installation than in the RAS installation.

Physical filters are used to physically separate solids from water (based on size) by capturing or filtering so that the material content is reduced. The function of the physical filter is to reduce the turbidity in the water caused by microorganisms and other particles, to lower the level of organic colloids, and to remove detritus from the biological filter. The filter bath in the RAS system comprised sand and silica sand which was quite effective at filtering out impurities, especially food residue, faeces, and carapace/skin from moulting. Active carbon sand (from charcoal) can purify water, removing odours and tastes. Silica sand is also useful in the process of water purification, and due to its small can serve to filter out impurities in the water.

The quality of water produced by the RAS system in this study was suitable to sustain life and promote the growth of blue swimming crab instar crablets. In the NON RAS system, the water changes can affect the growth of crablets in the culture tank, although the effects depend on the tank capacity and the condition of the crablets. Some factors influencing conditions in the tank during water change include changes in water temperature which easily stress the crablets during the process. According to Boonyapakdee & Bhujel (2019), temperature and salinity have significant effect to survival rate. Optimal temperature and salinity for crab larvae are 30^{o}C and 30 ppt, respectively (Ikhwanuddin et al 2012). In this study, salinity was in the 30-34 ppt range and temperature 26-30^{o}C. The instability in temperature and salinity may have affected the survival rate of crablets in both systems. One way to improve control over salinity and temperature in future RAS systems would be to make use of the Internet of Things (IoT) to enable control to be carried out automatically.

Although growth rate was increased, the RAS used in this study was unable to significantly reduce the mortality rate (Table 2). While daily temperature fluctuations were quite high and the effects of temperature and salinity fluctuations may play a role in determining crablet survival rates, cannibalism is also factor which can result in high levels of mortality. The shelters provided in the rearing tanks (plastic sheets) did not seem to provide sufficient shelter for the crablets. The availability of shelter is one of the abiotic factors which play a pivotal role in reducing mortality due to cannibalism and suppressing stress levels. In mitten crab (*Eriocheir sinensis*) aquaculture, the additional stocking of submerged aquatic vegetation has been used to ensure both high crab growth and a high survival rate (Zeng et al 2018). Some similar modification appears necessary for blue swimming crab culture.

Conclusions. In crab hatcheries, recirculating aquaculture systems (RAS) can have a positive effect on the growth of *Portunus pelagicus* instar crablets, most likely through the ability to maintain water quality parameters at levels closer to optimum compared to NON RAS systems. However, the RAS used was unable to reduce crablet mortality rate, suggesting the need for additional measures to reduce cannibalism and failed moulting.

Acknowledgement. We are grateful to Universitas Hasanuddin for research funds provided through the Universitas Hasanuddin Applied Research Program in 2020.

References

Appiah-Kubi F., 2012 An economic analysis of the use of recirculating aquaculture systems in the production of tilapia. MSc thesis, Norwegian University of Life Sciences, 40 pp.

Azra M. N., Ikhwanuddin M., 2015 Larval culture and rearing techniques of commercially important crab, *Portunus pelagicus* (Linnaeus, 1758): present status and future prospects. Songklanakarin Journal of Science and Technology 37(2):135-145.

Björnsson B., Ólafsdóttir S. R., 2006 Effects of water quality and stocking density on growth performance of juvenile cod (*Gadus morhua* L.). ICES Journal of Marine Science 63(2):326-334.

Chakraborty B. K., 2018 Effect of stocking density on survival, growth and production of mud crab juvenile by pen culture system of Bangladesh. International Journal of Oceanography and Aquaculture 2(4):1-11.

Boonyapakdee A., Bhujel R. C., 2019 Effects of nursing methods, astaxanthin supplementation and water quality on the survival of blue swimming crablets (*Portunus pelagicus* Linnaeus, 1758). Aquaculture Studies 19(1):45-56.

Chen Z., Chang Z., Zhang L., Jiang Y., Ge H., Song X., Chen S., Zhao F., Li J., 2019 Effects of water recirculation rate on the microbial community and water quality in relation to the growth and survival of white shrimp (*Litopenaeus vannamei*). BMC Microbiology 19:192.

Fujaya Y., Trijuno D. D., Aslamsyah S., Alam N., 2016 Domestication and selective breeding for producing fast growing and high meat quality of blue swimming crab (*Portunus pelagicus*). AACL Bioflux 9(3):670-679.

Hastuti Y. P., Nirmala K., Rusmana I., Affandi R., Kuntari W. B., 2017 Optimization of stocking density in intensification of mud crab *Scylla serrata* cultivation in the recirculation system. Jurnal Akuakultur Indonesia 16(2):253-260.

Ikhwanuddin, M., Azra, M. N., Talpur, M. A. D., Abol-Munafi, A. B., Shabdin, M. L., 2012. Optimal water temperature and salinity for production of blue swimming crab, *Portunus pelagicus* 1st day juvenile crab. AACL Bioflux 5(1):4-8.

KKP, 2015 Peraturan menteri kelautan dan perikanan Republik Indonesia nomor 1/PERMEN-KP/2015 tentang penangkapan lobster (*Panulirus* spp.), kepiting (*Scylla* spp.), dan rajungan (*Portunus pelagicus* spp.). pp. 1-4. [in Indonesian]

Murray F., Bostock J., Fletcher D., 2014 Review of recirculation aquaculture system technologies and their commercial application. Highlands and Islands Enterprise, University of Stirling Aquaculture, pp. 93-97.
Ravi R., Manisseri M. K., 2012 Efficiency of shelters in reducing cannibalism among juveniles of the marine blue swimmer crab, *Portunus pelagicus*. Israeli Journal of Aquaculture - Bamidgeh 64:1-6.
Shelley C., 2008 Capture-based aquaculture of mud crab (Scylla spp.). In: Capture-based aquaculture. Global overview. Lovatelli A., Holthus P. F. (eds), FAO Fisheries Technical Paper No. 508, Rome, FAO, pp. 255-269.
Trijuno D. D., Fujaya Y., Agviranti A., Marhama S., 2015 Quality of blue swimming crab *Portunus pelagicus* larvae from domesticated broodstock. Aquacultura Indonesiana 16(1):22-28.
Zeng Q., Jeppesen E., Gu X., Mao Z., Chen H., 2018 Cannibalism and habitat selection of cultured Chinese mitten crab: effects of submerged aquatic vegetation with different nutritional and refuge values. Water 10(11):1542.

Received: 18 October 2020. Accepted: 02 February 2021. Published online: 10 March 2021.
Authors:
Yushinta Fujaya, Fisheries Department, Faculty of Marine Science and Fisheries, Hasanuddin University, Jl. Perintis Kemerdekaan Km. 10, Tamalanrea, 90245, Makassar, South Sulawesi, Indonesia, e-mail: yushinta.fujaya@unhas.ac.id
Haryati, Fisheries Department, Faculty of Marine Science and Fisheries, Hasanuddin University, Jl. Perintis Kemerdekaan Km. 10, Tamalanrea, 90245, Makassar, South Sulawesi, Indonesia, e-mail: haryati_fikpunhas@yahoo.com
Sriwulan, Fisheries Department, Faculty of Marine Science and Fisheries, Hasanuddin University, Jl. Perintis Kemerdekaan Km. 10, Tamalanrea, 90245, Makassar, South Sulawesi, Indonesia, e-mail: sriwulancinga07@gmail.com
Besse Tenri Nurkamilah, Fisheries Department, Faculty of Marine Science and Fisheries, Hasanuddin University, Jl. Perintis Kemerdekaan Km. 10, Tamalanrea, 90245, Makassar, South Sulawesi, Indonesia, e-mail: bessetenrin04@gmail.com
Muawwana, Fisheries Department, Faculty of Marine Science and Fisheries, Hasanuddin University, Jl. Perintis Kemerdekaan Km. 10, Tamalanrea, 90245, Makassar, South Sulawesi, Indonesia, e-mail: muawwanaajm@gmail.com
Muhammad Niswar, Department of Informatics, Faculty of Engineering, Hasanuddin University, South Sulawesi, Indonesia, e-mail: mniswar@gmail.com; niswar@unhas.ac.id

How to cite this article:
Fujaya Y., Haryati, Sriwulan, Nurkamilah B. T., Muawwana, Niswar M., 2021 The effect of recirculating aquaculture system on blue swimming crab (*Portunus pelagicus* Linnaeus, 1758) instar crablet growth and survival rate. AACL Bioflux 14(2):718-724.