Growth and Survival of Blue Swimming Crab (*Portunus pelagicus* L.) In Different Rearing Substrates and Stocking Densities

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ABSTRACT

The study of the growth and survival of blue swimming crabs is important to optimize its production and explore the development of net-cage crab culture as the culture scheme for production of blue swimming crabs. This paper investigates the growth and survival rate of *Portunus pelagicus* at 15 and 30 days of culture using two rearing substrates (net and sand) and three stocking densities (15, 30 and 45 crabs/m2). Physicochemical parameters such as the dissolved oxygen, salinity, water temperature, and water transparency were also gathered across the days of culture to explain other factors that may influence survival rate of crabs during culture. Results showed no significant differences for both growth rate in terms of carapace width and body weight and survival rate. Significant interaction between the stocking rate and rearing substrates on the growth rate in terms of carapace width during the 15 days of culture were observed. Poor growth and survival rates of the crabs may have been the result of cannibalism and poor quality of bottom substrates like silt and abrupt change of water quality namely salinity and transparency. It is recommended to validate the results in a more favorable rearing environment. Management strategies to control predation may be tested and implemented when culturing blue swimming crabs in cages and pens.

Keywords: *blue swimming crab, survival rate, growth rate, stocking densities, rearing substrates*

INTRODUCTION

Among the invertebrates, the crabs are one of the most important resources that contribute significantly to the global food supply (FAO, 2014). The blue swimming crabs (*Portunus pelagicus* L.) have been a valuable component of small-scale coastal fisheries in many countries from the tropics (Mgaya et al. 1999; Batoy et al. 1980; Joel and Raj 1987). They are commercially important throughout the Indo-Pacific where they are sold as traditional hard shells or soft-shelled crabs, which are considered a delicacy throughout Asia (Edwards 1983). Blue crab, also known as 'alimasag' in Tagalog dialect of Filipino, ranks fourth among the high valued species in the Philippines (BFAR 2014).

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In the Philippines, catching of blue swimming crabs from the Western Visayas reached up to 21,074 tons in the year 1997, which represented 67.5% of the whole production in the country. Experts believe that the blue swimming crabs came from the Visayan Sea and Guimaras Strait (Malayang 2000). The Visayan Sea is one of the major crab fishing grounds of the country having 25 out of 53 picking stations in Region VI (Mesa et al. 2018). In 2001, the commercial catch of crabs amounted to 36,973 tons or 1.89% of the total marine production of the country (Ingles 2004). Crabs still classify as a highly valued species in the country. It ranks fifth in export volume and fourth in export receipts at 5,650 tons with a total value of Php 1.52 billion.

Global warming could adversely affect the fish stocks in the wild (Rahman et al. 2020; Reum et al. 2019), but the practice of crab culture in aquaculture has ensured the bringing of food as well as income to the families of the fishermen (Sarmiento 2008; McGoodwin 2001). In the strategic framework of the Philippine Development Plan from 2011 to 2016, the Philippine government goal was for improved food security and increased income (NEDA 2014). One of the strategies was to raise productivity and incomes of agriculture- and fishery-based household enterprises. Productivity enhancements in agriculture and fishery products will make the agriculture and fishery sector more competitive, which will contribute also to the growth of other economic sectors. Aquaculture has led to increased production. However, there is a need to develop the culture scheme of blue swimming crabs to optimize production.

The study of the growth and survival of any species in aquaculture is important to have a full understanding of its viability because it is necessary to consider the survival of a certain fishery species in terms of production (Andrés et al. 2010). In the early stages of a blue swimming crab's life, man should be kinder than nature (Tilburg et al. 2009; Tilburg et al. 2006). In the wild, it takes up to 30 days from the egg release to larval hatch, and to an inch-sized crab to move to a nursery ground. Out of the half-million fertilized eggs released by the female crab, 99.98% of the offspring will die without reaching the nursery ground (Epstein 2006).

In these premises, the need to have scientific data on the growth and survival rate of blue swimming crab in a suited substrate and to determine a favorable stocking density for production is significant. It aims to address the declining stocks through grow-out culture in net-cage and optimize production.

This study investigated the growth and survival of the blue swimming crab using sand and net rearing substrates with different stocking densities at 15, 30 and 45 crabs per square meter. It is to develop a net-cage blue swimming crab aquaculture with a favorable rearing substrate and stocking density.

METHODOLOGY

The study was conducted at Bocana, Ilog, Negros Occidental for the 30 days of culture observations from April to May 2014. The blue swimming crabs (*Portunus pelagicus*) with sizes ranging from six to seven centimeters and initial body weight of 16 grams were gathered from the locality. The physicochemical parameters such as soil pH, water pH, dissolved oxygen, salinity, temperature, and water transparency that could affect the growth and survival rate of the blue swimming crab were collected and presented in the results.

The crabs were sorted and stocked in terms of sex for the ratio of one male to one female. Two substrates were compared: net for net cage and sand for net-pen. The net pen had a dimension of 1 x 1 x 1.5 meters (l x w x h), and the net cage measured 1 x 1 x 0.5 meter (l x w x h). Three variables for stocking densities were compared, composed of 15, 30, and 45 crabs per square meter for each substrate with three replications. The experiment was laid out using the Factorial Randomized Complete Block Design (FRCBD): factor one as the type of substrate or cage and factor two as the stocking density. Carapace width and weight of crabs were measured to determine the growth of the crabs.

The carapace width and weight of crabs were measured to determine the growth of the crabs. The carapace length was measured across the top shell between the two lateral (outermost) spines. This was taken individually before stocking, in 15 DOC and during harvest getting its final CW. The following formula was used to measure the average carapace width: $CW_{ave} = CW_t / NS_{trt}$, where CW_{ave} is the average carapace width, CW_t is the total carapace width of all stocks, and NS_{trt} is the number of stocks per treatment. The weight of crabs was taken individually using a weighing scale (grams) following its tagging. This was done before stocking and every other 15 DOC intervals. The final WG was taken after harvesting using the following formula: $WG = (ABW_p – ABW_i)/ DOC$, where WG is the weight gain, DOC is the days of culture or period of interval (POI), ABW_i is the initial average body weight, and ABW_p is the present average body weight. The growth rate of the crabs was obtained by dividing the weight gained by the period of interval, determining the growth increment of the crabs, using the following formula: GR = WG/POI, where GR is the growth rate, WG is the weight gain, and POI is the period of interval or the difference between the present DOC and previous DOC. The survival rate of the crabs was recorded daily from the day after stocking until harvest. This was done daily by monitoring every 6:00 am and 6:00 pm. The remaining number of stocks per treatment was counted and recorded. In getting the survival rate the following formula was used: $SR = NS_p / SD \times 100$, where SR is the survival rate, NS_p is the present number of stocks, and SD is the stocking density. Data were analyzed using Analysis of Variance (ANOVA) and Duncan's Multiple Range test (DMRT) to compare treatment means.

RESULTS

Physicochemical Characters of Culture Environment

The culture environment of the blue swimming crabs in Bocana, Ilog, Negros Occidental during the 30 days of culture from April to May 2014 had average soil pH of 7.02, water pH of 6.90, dissolved oxygen of 3.40 ppm, salinity of 23.42 ppt, and water temperature of 27.07 ºC (Table 1). Salinity and transparency significantly dropped during the 18th day of culture (Fig. 1).

Table 1. *Range and mean value of soil pH, water pH, dissolved oxygen (ppm), salinity, water temperature (ºC), and water transparency (cm) at Bocana, Ilog, Negros Occidental during the experiment from April to May 2014.*

Physicochemical Parameters	Range		Mean
	Lowest	Highest	
Soil pH	6.60	7.40	7.02
Water pH	6.10	7.20	6.90
Dissolved Oxygen (ppm)	1.24	7.80	3.40
Salinity (ppt)	4.00	33.00	23.42
Water Temperature (°C)	24.60	30.20	27.07
Water Transparency (cm)	10.00	36.00	30.48

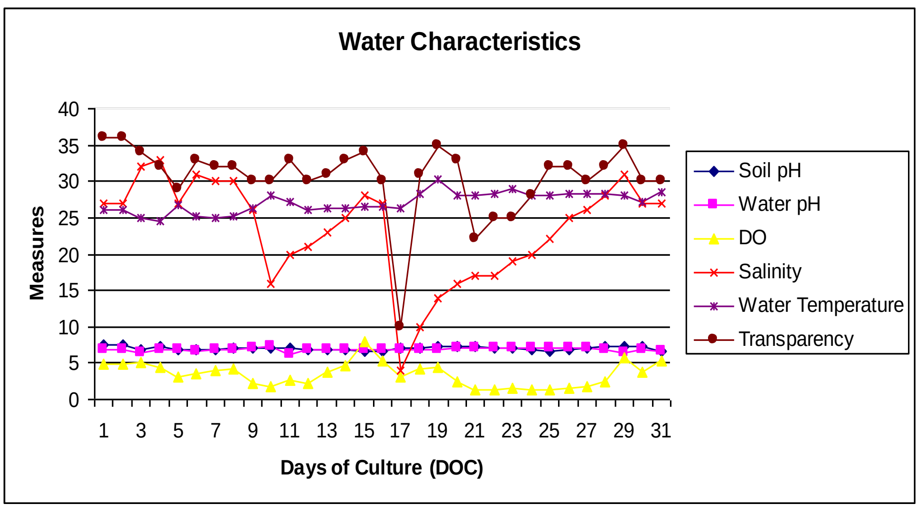

Figure 1. Water characteristics across the 30 days of culture of blue swimming crabs.

Growth Parameters in Different Rearing Substrates and Stocking Densities

The growth rates in terms of increase in carapace width after 15 and 30 days of culture were not significant for both rearing substrates and stocking densities (Table 2). But the sand substrate (net-pen) had the higher percentage of carapace width increase when compared to net substrate (net cage) and stocking density of 45 crabs per square meter had the highest percentage of increase in carapace width among the stocking densities. A significant interaction between rearing substrates and stocking densities in terms of carapace width at day 15 was observed (Fig. 2). But no significant interaction existed between rearing substrates and stocking densities at day 30 observation. It was observed there was a 0.7 cm up to 2.15 cm increase in carapace width after successful molting process (Fig. 3).

Table 2. *Growth rate (percentage of increase) in terms of carapace width of blue swimming crabs at different rearing substrates and stocking densities at 15 and 30 days of culture observations.*

Rearing Substrates	Stocking Densities (crabs/m^2)	Increase in Carapace Width (%)	
		After Day 15	After Day 30
Net (net cage)	15	0.76	0.00
	30	0.56	0.00
	45	1.39	4.33
	Means	**0.90**	**1.44**
	F-test	**ns**	**ns**
Sand (net-pen)	15	0.58	2.56
	30	2.09	3.00
	45	0.61	3.11
	Means	**1.09**	**2.89**
	F-test	**ns**	**ns**
Total Means	15	0.67	1.28
	30	1.32	1.50
	45	1.00	3.72
	Grand Mean	**1.00**	**2.17**
	F-test	**ns**	**ns**

Note: ns-not significant at 5% level.

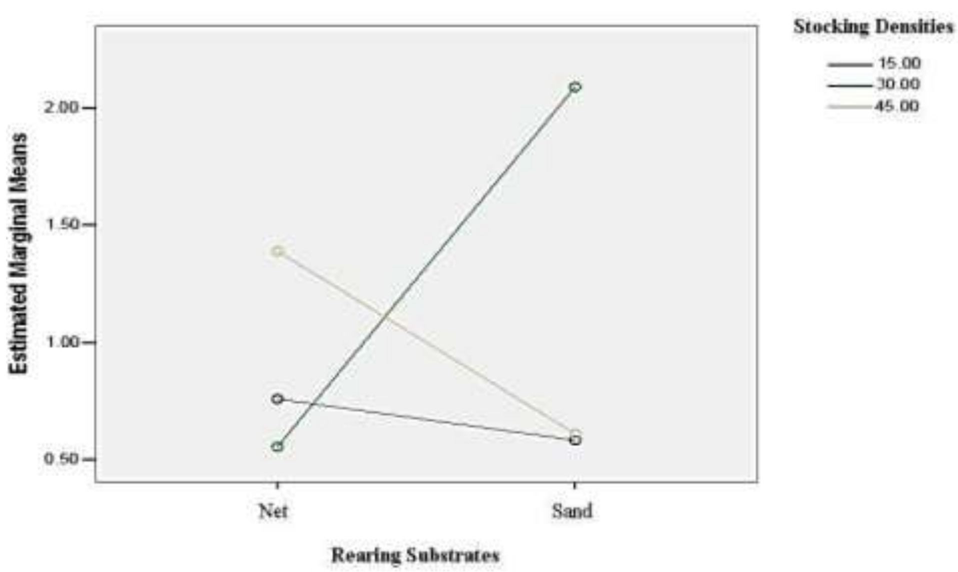

Figure 2. Comparison of the estimated marginal means of carapace width of blue swimming. crabs at day 15 of observation between the different rearing substrates and stocking densities.

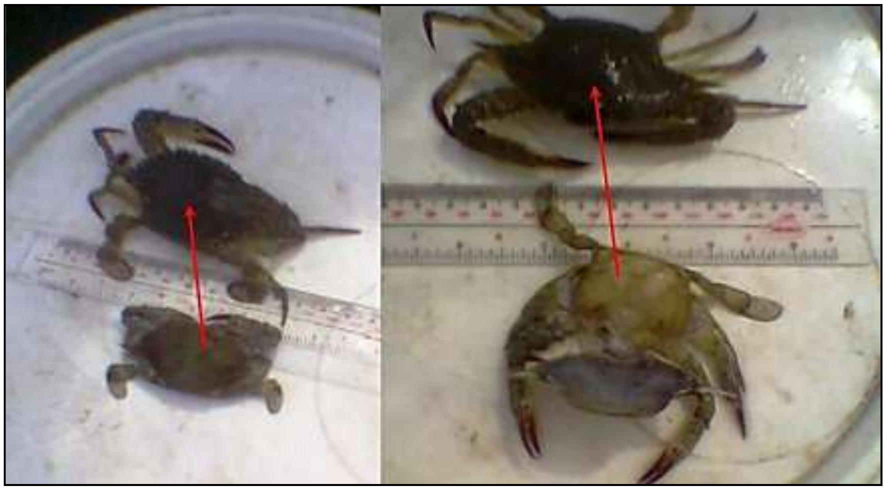

Figure 3. Comparison of carapace width after a successful molting process of blue swimming crabs.

The growth rates in terms of body weight after 15 and 30 days of culture were not also significant for both rearing substrates and stocking densities (Table 3). Similarly, the sand substrate (net-pen) had the higher growth rates in terms of body weight increase when compared to net substrate (net cage) and the stocking density of 45 crabs per square meter had the highest percentage of increase in body weight among the stocking. No significant interaction was observed between the rearing substrates and stocking densities on the growth rates in terms of body weight of blue swimming crabs both at day 15 and day 30.

Table 3. *Growth rate (percentage of increase) in terms of body weight of blue swimming crabs at different rearing substrates and stocking densities at 15 and 30 days of culture observations.*

Rearing Substrates	**Stocking Densities (crabs/m^2)**	**Increase in Body Weight (%)**	
		After Day 15	**After Day 30**
Net (Net cage)	15	52.52	0.00
	30	26.42	0.00
	45	47.50	24.00
	Means	**42.15**	**8.00**
	F-test	ns	ns
Sand (Net-pen)	15	68.22	32.22
	30	39.37	48.22
	45	32.32	39.11
	Means	**46.64**	**39.85**
	F-test	ns	ns
Total Means	15	60.37	16.11
	30	32.90	24.11
	45	39.91	31.56
	Grand Mean	**44.39**	**23.93**
	F-test	ns	ns

Note: ns-not significant at 5% level

Survival Rates of Blue Swimming Crab

The survival rates of blue swimming crabs after 15 and 30 days of culture were not significantly different for both rearing substrates and stocking densities (Table 4). Net cage had higher survival rates than net-pen at day 15 but otherwise at day 30. Stocking density of 30 crabs/m2 had the highest survival rates. No significant interaction observed between the rearing substrates and stocking densities for both day 15 and 30 culture observation. Dead blue swimming crabs during the 1st and 2nd week of culture were observed to have cracks in the carapace and loss of appendages (Fig. 4). During the 3rd and 4th week of observation, dead crabs found were in their intermolt (Fig. 5). The carapace and the body of crabs were still intact, but silt was seen on the crabs' bodies. Survival rate was decreasing across days of culture, with a greater drop on the first 15 days of culture and moderate reduction in the remaining 15 days of culture (Fig. 6).

Table 4*. Survival rates of blue swimming crabs at different rearing substrates and stocking densities at 15 and 30 days of culture observations.*

Rearing Substrates	**Stocking Densities (crabs/m^2)**	**Survival Rates**	
		After Day 15	**After Day 30**
Net (Net cage)	15	36.67	0.00
	30	43.33	0.00
	45	43.33	3.33
	Means	**41.11**	**1.11**
	F-test	**ns**	**ns**
Sand (Net-pen)	15	20.00	3.33
	30	40.00	6.67
	45	30.00	3.33
	Means	**30.00**	**4.44**
	F-test	**ns**	**ns**
Total Means	15	28.33	1.67
	30	41.67	3.33
	45	36.67	3.33
	Grand Mean	**35.56**	**2.78**
	F-test	**ns**	**ns**

Note: ns-not significant at 5% level

Figure 4. Cracks of carapace and loss of appendages observed on the dead blue swimming crabs during the 1st and 2nd week of culture.

Figure 5. Dead blue swimming crabs were collected during the 3rd and 4th week of culture across treatments as a result of abrupt change in the water quality.

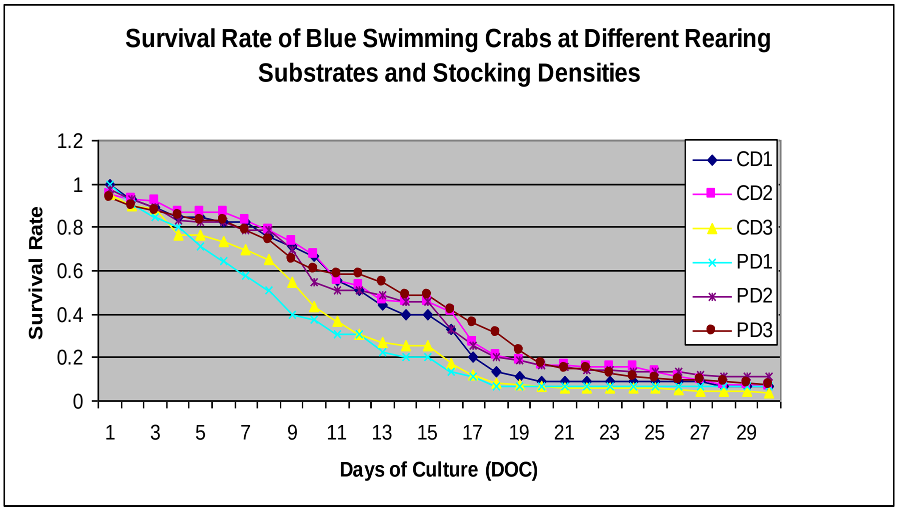

Figure 6. Survival rates of blue swimming crabs at different rearing substrates and stocking densities (CD1-3: Net Substrate; PD1-3: Sand Substrate).

DISCUSSION

Environmental factors, specifically the water characteristics for a crab's life can greatly affect their growth. The physico-chemical characteristics for our crab culture were below the standard value for water quality by the Coastal Fisheries Research and Development Bureau, Marine Shrimp Culture Research Institute, Department of Fisheries of Thailand. Among the standard values, soil pH and water transparency were within the standard value range. Upon stocking, the blue swimming crabs swam fast when they were placed into both net pens and cages. Blue swimming crabs stayed at the top of the cage attaching their appendages to the net at night time especially during flood tide. In the daytime, they stayed at the bottom of the cage or pen. It was observed that trash fish feeds were not totally consumed if the transparency and salinity declined. Crabs as observed fed on filamentous algae and some species of small fishes and shrimps from the surrounding areas which accidentally entered the net pens and cages. This observation was similar with that of Lipcius et al. (2006) that crabs have a catholic diet and with Zohar (2004) who observed that juvenile blue crabs feed mostly on benthic macroinvertebrates, small fishes, dead organisms, aquatic vegetation, and associated fauna.

During the fourth day of the culture period, cannibalism was observed. The net substrate with the stocking density of 45 crabs/m^2 had numerous dead crabs. Cracks on the carapace and loss of body parts in some crabs were observed as signs of cannibalisms. The higher stocking density of crabs during the 1st and 2nd week may be the cause of cannibalisms when compared with that for the 3rd and 4th week. According to the report, cannibalized blue crabs make up as much as 13% of a crab's diet and the crabs that are poor in health, with missing appendages, heavily fouled with other organisms, and at molting process are more likely to be cannibalized (Wilcox 2007). Bottom substrates, water mass movement, and toxicants of the soil and water were considered to have influenced the survival of crabs (Chou et al. 1999) which may have been the cause for the low survival rate of the crabs during the experiment.

The observed increase in the carapace width of crabs after a successful molting process was similar with the findings of the Sea Science of South Carolina Department of Natural Resources (2002) that the resulting soft crab, which is limp and wrinkled, swelled to normal shape increasing in size by 25 to 35%. These findings, were similar with the findings of Zinski (2006) who noted that the new shell was roughly one-third or 33% larger than the old shell. Dead crabs which died in the process of molting were probably observed because of toxicants present in the soil or by siltation since silt was seen on the crabs' bodies while the carapace and the bodies were still intact. For the salinity to be suitable for the culture of early juvenile *P. pelagicus*, it should range from 20 to 50 ppt (Romano and Zeng 2006). During the culture period, salinity suddenly dropped on the 18th day and mortality rate was 50% during this period. Heavy rains occurred during the 18th day and records showed a sudden drop in salinity, dissolved oxygen and water transparency. Whitaker (2005) reported that young crabs within the estuaries are vulnerable to drought, flood, or unseasonable temperatures.

The growth rates in terms of carapace width of blue swimming crabs were not significantly different. Results obtained did not differ significantly mainly because of lower successful molts since the growth of blue swimming crabs is primarily influenced by molting (Hines and Ruiz 1995). During this process they are very susceptible to cannibalism (Romano and Zeng 2016). Related studies also found that cannibalism while molting is one of the causes of low survival of crabs (Whitaker 2005; Zmora 2005; Ryer et. al. 1997). During the molting process, the crab is highly vulnerable to predators (Wilcox 2007; Zinski 2006). Blue crabs stop eating and look for shelter to avoid predation during this process. Crabs are not able to grow in terms of weight since they are not free to look for food and are incapable of protecting themselves. Even though the results were not significantly different, growth increments during their intermolt were observed on the tissue content of the crabs as also observed by Andrés et al. (2010). Minimum weight increase through relative changes in tissue content during the intermolt period was also observed by Jose and Menon (2005), Zinski (2006) and Nguyen et al. (2014). In their natural habitat, blue swimming crabs grow well in sandy or muddy bottoms at 10 to 50 meters deep for they stay buried under sand or mud most of the time. The lower survival response of crabs implies that it would be better to rear them in the open areas which are deeper than the shallow river-mouth. (FAO 2009).

CONCLUSION

Salinity and water transparency were among the physicochemical parameters that greatly affected the survival rate of the blue swimming crab. Culturing of blue swimming crabs should be away from the river mouth to avoid sudden change in water characteristics because of heavy rains which can result in poor survival of crabs being cultured. Cannibalism between blue swimming crabs is the main constraint in culturing this crab species using net-cage culture schemes. Higher stocking density of crabs results in cannibalism. In order to test the survival of blue swimming crabs in different rearing substrates and stocking densities, another experiment should be conducted away from the river mouth. In this experiment, optimum stocking densities that prevent cannibalism among blue swimming crabs should be determined

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