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Original Article

Distribution, body size, and eggs of ovigerous swimming crab (*Portunus pelagicus* Linnaeus 1758) at various habitats in Lasongko Bay, Central Buton, Indonesia

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Abstract: The distribution, body size, and egg diameter and volume of ovigerous blue swimming crabs, *Portunus pelagicus*, were examined according to habitat type and egg color in Lasongko Bay, Central Buton, Indonesia between April 2013 and March 2014. Ovigerous female crabs were sampled using gillnets and traps at seven stations. Based on the results, the ovigerous female crabs with yellow to dark gray eggs were found over a range of depths from 0.35 to 31.0 m, on sandy to muddy substrate, and in sea bottom covered by seagrass and in bare areas. The carapace widths of the ovigerous female crabs varied significantly between the types of habitat, egg color, and season. Wet weight, diameter, and volume of eggs increased by 36.35%, 25.16%, and 91.76%, respectively, with embryonic development, while the dry weight of eggs decreased by 1.86%. Ovigerous blue swimming crabs with different levels of embryonic development showed a wide habitat distribution from shallow to deeper waters.

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Introduction

The blue swimming crab, *Portunus pelagicus* Linnaeus 1758, distributes at diverse habitats inhabiting in coastal waters of the continental shelf to a depth of 50 m (Edgar, 1990), and a maximum depth of over 65 m (Juwana, 1997). In coastal waters, this crab can be found in the intertidal regions, mouths of small rivers (creeks), sublittoral zones, shallow bays, and coastal waters (Edgar, 1990; Chande and Mgaya, 2003; de Lestang et al., 2003) with seagrass and algal beds with mud, clay, and sand substrates (Chande and Mgaya, 2003; de Lestang et al., 2003; Dineshbabu et al., 2008). This species is also found in mangrove areas in brackish water ponds adjacent to the sea (Juwana, 1997). This crab is found from the head to the mouth of Lasongko Bay, Central Buton, Indonesia in varying habitat conditions, depth, substrate type, and presence/absence of seagrass. In Lasongko Bay, this crabs caught in shallow waters that are smaller than those from deeper locations (Hamid, 2011).

Early development of the ovigerous female crabs usually occurs in estuaries and in shallow waters, and they migrate to deeper waters for spawning (Sumpton et al., 1994; Kangas, 2000). The blue swimming crab is usually found in clear water with sandy substrate, with high levels of oxygen and salinity to support the development and survival of newly hatched larvae (Sumpton et al., 1994; Kangas, 2000; Xiao and Kumar, 2004). Inhabiting ovigerous female crabs in the estuary are smaller or younger than those of deeper parts of the bay (Kangas, 2000). The distribution of ovigerous female crabs varies spatially and is usually influenced by water depth, sediment fraction, and seagrass condition (Nitiratsuwan et al., 2010, 2013; Zairion et al., 2014). Nitiratsuwan et al. (2013) studied the distribution of ovigerous female crabs according to

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habitat type, but not based on the color of their eggs. Therefore, the distributions of ovigerous female crabs based on egg color and in relation to the type of habitat have not been reported.

Crab eggs change color during embryonic development, starting from yellow, and progressing to orange, brown, and finally gray or black, and also change in shape, diameter, and volume (Arshad et al., 2006; Samuel and Soundarapandian, 2009; Soundarapandian and Tamizhazhagan, 2009; Liao et al., 2011; Ravi and Manisseri, 2013). As the eggs grow in diameter, volume, and wet weight, the largest size is obtained on the second day before the end of the embryonic development (Ravi and Manisseri, 2013). There have been relatively few studies on the diameter of eggs related to color change in ovigerous female swimming crabs (Potter et al., 2001; Arshad et al., 2006; Soundarapandian and Tamizhazhagan, 2009; Ikhwanuddin et al., 2011, 2012; Ravi and Manisseri, 2013; Safaie et al., 2013). In a recent study, Soundarapandian and Tamizhazhagan (2009) determined the diameters of eggs from yellow to dark gray, but they did not record the volume of eggs for each color. The present study was performed to elucidate the distribution, body size, and egg size (diameter and volume) of ovigerous female crabs in relation to habitat type and egg color in Lasongko Bay, Central Buton, Indonesia.

Materials and Methods

Study area and sampling: This study was conducted between April 2013 and March 2014 in Lasongko Bay (Latitudes: 05°15'S and 05°27'S and longitudes: of 122°27'E and 122°33'E). Crabs were collected at seven stations (Fig. 1). Sampling stations were characterized with regard to seagrass condition, substrate type, and water depth (Table 1).

The ovigerous female crabs were caught monthly using bottom gillnets with mesh sizes of 3.8, 5.8, and 8.9 cm and also with traps. The collected crabs were kept in an icebox and stored in a freezer prior to examination in the laboratory.

A total of 168 ovigerous female crabs were caught, consisting of 57 with yellow eggs, 48 with orange eggs, 31 with brown eggs, and 32 with dark gray eggs. All samples were weighed using a digital scale with a precision of 0.01 g. Carapace width was measured to a precision of 0.05 mm. The eggs on the abdomen were gently removed from pleopods, weighed, and dried at 65°C for 24 hrs. For each egg color, three crabs were used to determine the number and diameter of the eggs. All measurements were conducted with the assumption that the eggs were spherical (Figueiredo and Narcisoi, 2008).

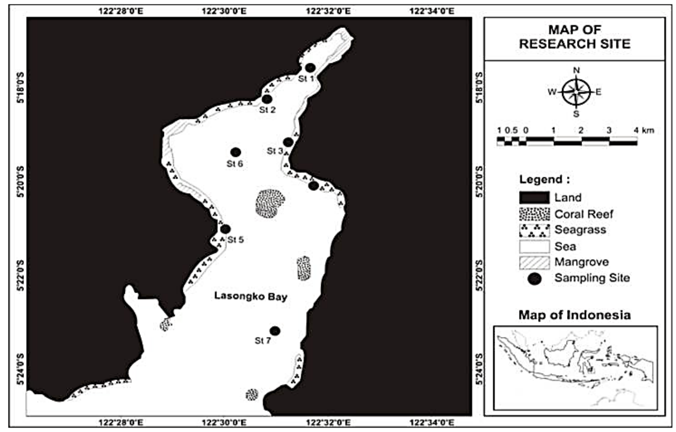

Figure 1. Map of study sites and sampling stations in Lasongko Bay, Central Buton, Indonesia.

Data analysis: Body and egg sizes of the ovigerous females according to station and egg color were analyzed using one-way ANOVA followed by Tukey's test. The sizes in different seasons were analyzed by t-test assuming unequal variance. The size and egg's data were tested for normality using the Kolmogorov-Smirnov test (Steel and Torrie, 1992), and if significantly different, the data were transformed to log 10 before one-way ANOVA and examined by t-test. Linear regression analysis was used to determine the relationship between fresh weight and dry weight of crab eggs. In all analyses, $P<0.05$ was taken to indicate statistical significance.

Results

Distribution of ovigerous female blue swimming crabs: Distribution of the ovigerous female crabs was determined based on the color of eggs and habitat type along with data from catches by fishermen in the study area (Table 2). The ovigerous female crabs

Table 1. Characteristics of crab habitat type at each station in Lasongko Bay, Central Buton, Indonesia.

Station	Characteristics of habitat type			
	Depth (m)	**Substrate type**	**Bottom condition**	**Seagraass bead condition**
1	0.35-6.10	Sand, Sand clay	Covered seagrass, Bare sand	Less–dense, *Enhalus acoroides* dominated
2	0.35-6.60	Sand, usually rock	Covered seagrass, Bare sand	Less–dense, *Thalassia hemprichii* less-dense
3	0.62-8.85	Sand, Sand clay	Covered seagrass, Bare sand	Moderat–dense, *T. hemprichi* dominated
4	0.40-13.02	Sand, Sand clay	Covered seagrass, Bare sand	Moderat–dense, *T. hemprichi* dominated
5	0.35-9.50	Sand, Sand clay	Covered seagrass, Bare sand	Moderat–dense, *T. hemprichi* dominated
6	3.65 - 9.55	Sand, Loam clay sand	Bare sand	No seagrass
7	14.00-31.00	Clay	Bare sand	No seagrass

Table 2. Distribution of the ovigerous female of blue swimming crabs (*Portunus pelagicus*) according to habitat type in Lasongko Bay, Central Buton, Indonesia.

Station	Habitat Type				Distribution of ovigerous female crabs based on eggs color			
	Depth (m)	**Substrate Type**	**Bottom Condition**	**Turbidity (NTU)**	**Yellow**	**Orange**	**Brown**	**Dark gray**
1	0.35-2.35	Sand	Seagrass ++	2.79	√	√	√	0
	1.60-3.65	Sand	Seagrass +	2.14	√	√	√	√
	2.65-6.10	SC	Bare sand	2.18	√	√	0	√
2	0.35-2.15	Sand	Seagrass ++	1.99	√	√	0	0
	1.70-3.30	Sand	Seagrass +	2.27	√	√	√	√
	3.70-6.60	Sand	Bare sand	1.60	√	0	√	√
3	0.62-2.25	Sand	Seagrass ++	1.36	√	√	√	0
	2.00-3.71	Sand	Seagrass +	0.99	0	√	√	√
	4.00-8.85	Sandy Clay	Bare sand	1.55	√	√	√	√
4	0.40-2.50	Sand	Seagrass ++	1.53	√	√	√	√
	2.00-3.30	Sand	Seagrass +	1.06	0	0	√	0
	8.85-13.02	Sandy Clay	Bare sand	1.04	√	0	√	√
5	0.35-2.60	Sand	Seagrass ++	1.44	√	√	0	√
	2.10-3.77	Sand	Seagrass +	1.39	0	√	√	√
	4.70-9.50	Sandy Clay	Bare sand	1.17	0	0	0	0
6	3.65-9.55	Sand, Loam Clay Sandy	Bare sand	1.18	√	√	√	√
7	14.0-31.0	Clay	Bare sand	1.18	√	√	√	√

++: densely; +: Less dense; BS: bare sand; √: found; 0: not found

with eggs of four different colors (yellow, orange, brown, and dark gray) in Lasongko Bay were found in several types of habitat, i.e., at depths of 0.35 m (low tide) to 31.0 m (high tide), on various substrate types from sand to clay, as well as under substrate conditions of sand to overgrown seagrass (Table 2).

The proportion of ovigerous female crabs caught at each station ranged from 6.72% to 35.00%, with

Table 3. Sizes of ovigerous female in blue swimming crabs (*Portunus pelagicus*) based on station, egg color, and season.

Variable	Specimen number	Carapace width (mm)	Body weight (g)
Based on the station			
1	15	113.2±10.0^{bc}	103.22±27.27^{b}
2	8	104.4± 6.0^{c}	80.60±10.44^{b}
3	27	118.3±15.0^{ab}	137.42±50.35^{ac}
4	48	122.5±9.2^{ab}	139.14±35.82^{ac}
5	20	116.7±10.7^{ab}	118.98±34.75^{ac}
6	29	115.4±10.8^{b}	113.51±31.17^{b}
7	21	125.0±13.3^{a}	150.72±54.57^{a}
Based on the color of egg			
Yellow	57	119.1±9.9^{a}	123.62±33.39^{a}
Orange	48	119.2±10.2^{a}	129.69±33.84^{a}
Brown	31	117.6±7.3^{a}	119.76±25.52^{a}
Dark grey	32	121.6±8.7^{a}	142.16±33.83^{a}

Column and the same item and followed the same letter show no significantly different (P>0.05)

Table 4. Weight, diameter, and volume of eggs from ovigerous female blue swimming crab (*Portunus pelagicus*) according to egg color.

Eggs color	Number	Egg wet weight (g)	Egg dry weight (g)	Egg diameter (μm)	Egg volume (μm^3)
Yellow	30	17.14±8.08^{a}	4.31±2.01^{a}	249.2±26.5^{a}	8.5 x 10$^{6\ a}$
Orange	29	18.39±8.30^{a}	4.18±1.61^{a}	291.6±19.4^{b}	13.2 x 10$^{6\ b}$
Brown	26	20.00±7.55^{a}	4.65±1.92^{a}	310.3±17.8^{c}	15.9 x 10$^{6\ c}$
Dark grey	25	23.37±0.56^{a}	4.23±1.78^{a}	311.9±21.4^{c}	16.3 x 10$^{6\ c}$
Changes (%)		+36.35	-1.86	+25.16	+91.76

+ = Increase; - = Decrease; Column of the same followed the same letter show no significantly different (P>0.05)

the highest found at station 7 and the lowest at station 2. The proportion of ovigerous female crabs during the study period found at depths ranged 1.5-2.5 m on sandy substrate and dense seagrass coverage was 11.95%, and that at depths ranging from 2.5 to 3.5 m on sandy substrate and seagrass coverage was less than 13.33%. The proportion of ovigerous female crabs at depths ranging from 5 to 12 m on sandy-clay type substrate with a bare sand bottom was 10.14%.

The rates at which ovigerous female crabs were caught at stations 6 and 7 were higher than other stations, and those with eggs of all four colors were found at stations 6 and 7. Stations 6 and 7 were located far from intertidal areas. Characteristic habitat types of the ovigerous female crabs at station 6, which is located in the central part of the bay at depths ranging 3.65-9.55 m, were sand and sandy-clay loam substrates, with relatively clear water and bare sandy bottom. Station 7, which is located at the mouth of the bay at depths ranging from 14.0 to 31.0 m, had a clay type substrate with clear water and fine bare sand on the bottom. At the other five stations, all of which were directly related to intertidal zones at water depths ranging from 0.35 m (low tide) to 13.5 m (high tide), the substrates were generally sandy with overgrown seagrass, and stations 1 and 2 had relatively high turbidity levels (Table 2).

Body size of ovigerous female Crabs: The ovigerous female crabs caught in the Lasongko Bay ranged 86.6-162.3 mm in carapace width and 42.75-314.22 g in total weight. The mean carapace width at each station (habitat type) ranged 104.4-125.0 mm with body weight ranging 80.60-150.72 g. The largest crab was found at station 7 and the smallest one at station 2. There were significant differences in body size of the ovigerous female between stations (P<0.05), but not with regard to egg color (P>0.05) (Table 3).

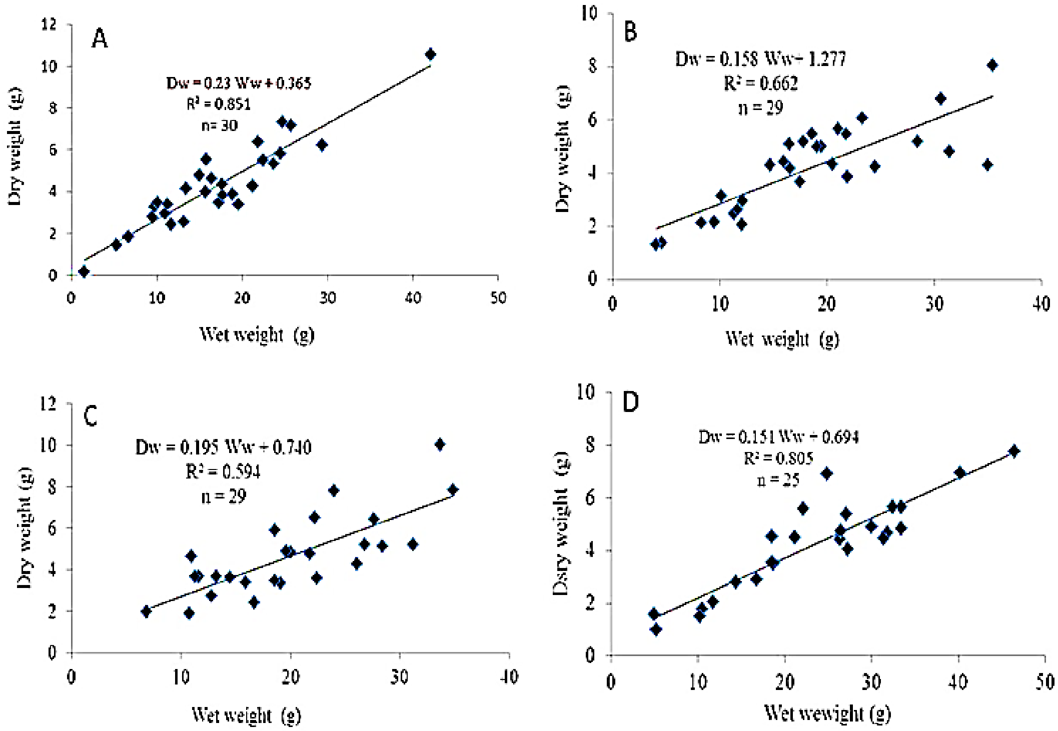

Figure 2. Relationship between wet weight (Bb) and dry weight (Bk) of (A) yellow, (B) orange, (C) brown, and (D) dark gray ovigerous blue swimming crab (*Portunus pelagicus*) eggs.

Egg weight, diameter, and volume: The wet weight of eggs caught during the study period ranged from 1.50 to 46.47 g, while the dry weight of eggs ranged from 0.17 to 10.55 g. The wet weight of ovigerous female crab eggs increased by 36.35%, whereas the dry weight decreased by 1.86% with changes in egg color from yellow to dark gray. However, differences in wet and dry weights of crab eggs according to color were not significant ($P>0.05$) (Table 4).

The wet and dry weights of eggs for each of the four crab egg colors showed a highly significant, strong, and positive correlation ($P<0.01$) (Fig. 2). These observations indicate that dry weight increased with increasing wet weight of eggs with changing color. The greatest weight gain for dried eggs was for those of yellow and the lowest was for eggs with dark gray colour (Fig. 2), indicating that the water content of yellow crab eggs is lower than others.

The eggs ranged 180-400 μm in diameter as color changed from yellow to dark gray, with an average of 249.2-311.9 μm. The egg diameter increased 25.16% with changing its color from yellow to dark gray. The volume of crab eggs ranged from 3.1×10^6 to 33.5×10^6 μm^3, with an average of 8.5×10^6-16.3×10^6 μm^3, and increased by 91.76% from yellow to dark gray (Table 4). Both the diameter and volume of eggs differed significantly between ovigerous crab eggs of different colors ($P<0.05$).

Discussion

Distributions of ovigerous female crabs by habitat type: Ovigerous female crabs in Lasongko Bay with varying egg colors were found in various habitat types and occurred in all months during the study period, with the highest proportion in November and the lowest in September (Hamid et al., 2015). The distribution of ovigerous female crabs in Lasongko Bay according to the color of their eggs showed no clear pattern in relation to the different habitat types as characterized by water depth, type of substrate, and bottom water and turbidity conditions. This is in contrast to previous studies (Kangas, 2000; Potter and de Lestang, 2000; Potter et al., 2001; de Lestang et al., 2003; Nitiratsuwan et al., 2013) in which the distribution of ovigerous female crabs was influenced by depth, substrate type, and water

Table 5. Mean egg diameter and volume of blue swimming crab (*Portunus pelagicus*) according to egg color at several locations.

Location (Source)	Eggs color	Diameter (µm)	Volume (µm^3)
Parangipettai, Tamil Nadu, India (Soundarapandian and Tamizhazhagan, 2009)	Yellow	350-380	-
	Orange	390-400	-
	Brown	400-410	-
	Dark grey	410-420	-
Palk Bay, Mandapam, India (Ravi and Manisseri, 2013)	Yellow	324	15 x 10^3
	Blackish		21 x 10^3
Cockburn Sound, Australia (Poter et al., 2001)	Orange clear	235-324	-
	Brown	320	-
Sematan Coast, Serawak, Malaysia (Ikhwanuddin et al., 2011)	Yellow-orange	373.4	9.3 x 10^{6*}
	Brown	383.2	
	Black	390.3	
Port Dickson, Johor Coast, Malaysia (Ikhwanuddin *et al*., 2012)	Yellow	307	-
	Yellow	386	-
	Orange	396	-
Persia Gulf and Oman Sea, Iran (Safaie et al., 2013)	Yellow	300	-
	Yellow - grey	300	-
	Grey	310	-
Lasongko Bay, Indonesia (This study)	Yellow	249.2	8.5 x 10^6
	Orange	291.6	13.2 x10^6
	Brown	310.3	15.9 x 10^6
	Dark grey	311.9	16.3 x 10^6

- = Data not available; * = the average of the three color eggs

turbidity. The four different egg colors of ovigerous females in Lasongko Bay were found at almost equivalent ratios in a variety of habitat types.

Some previous studies (Potter et al., 1983; Sumpton et al., 1994; Kangas, 2000; Xiao and Kumar, 2004) indicated that ovigerous female crabs migrated to clear water with sandy substrates for spawning and hatching of eggs. The ovigerous females with dark gray eggs were found in all types of habitat, but stations 1, 2, and 3 at depths ranging from 0.35 to 2.35 m and overgrown with dense seagrass, and also at station 4 with a depth ranging from 2.0 to 3.30 m and with less dense seagrass. These observations indicates that the spawning and release of crab larvae in Lasongko Bay did not always occur in deep, and clear water. Thus, spawning and larval release occurred in various types of habitat, from shallow seagrass areas at a depth of approximately 0.35 m (low tide) with sandy substrate to locations 31 m (high tide) deep with fine sand (dominated by clay) and in relatively high turbidity (2.27 NTU) to relatively clear water (0.99 NTU).

The basis for determining larval release location was based on the fact that the dark gray eggs of ovigerous female crabs hatch within a period of 12 to 24 hours (Arshad et al., 2006). This was also confirmed by the observations of crab fishermen in Lasongko Bay, who temporarily store ovigerous female crabs with dark gray eggs in cages for 16 hours, after which the crabs no longer have eggs on their abdomens (i.e., they have released their eggs). Some researchers (Sumpton et al., 1994; Potter and de Lestang, 2000; de Lestang et al., 2003) mentioned that crabs in bay ecosystems often do not migrate when spawning, and under certain conditions when there is a change in salinity, crabs spawn in the waters of bays with high salinity. The average salinity at the study site was relatively high, ranging from 29.5 to 33.4 psu, which supported spawning and hatching of crab eggs. Ovigerous female crabs spawn, and their eggs hatch, at salinities of 26-32 psu (Juwana, 2006), and the optimum salinity for growth of larvae is 30 psu (Ikhwanuddin et al., 2012b). Further tagging studies are needed to determine the migration patterns of ovigerous female crabs and the distribution of their larvae in Lasongko Bay.

Body size and egg volume and diameter: Body size of ovigerous females showed greater variation between seasons than stations or egg colors. The ovigerous females caught at station 7 were larger than those caught at other stations, especially stations 1 and 2. Station 7 is located at the mouth of the bay with deeper water (14-31 m), while stations 1 and 2 are located on the inner side of the Lasongko bay near the coastline with muddy and shallow habitats (1-4 m) and a low density of seagrass beds. Crab carapace width of ovigerous females in this study was in the range reported works (32-193 mm) (Batoy et al., 1987; de Lestang et al., 2003; Arshad et al., 2006; Johnson et al., 2010; Kamrani et al., 2010; Ikhwanuddin et al., 2011, 2012a; Josileen, 2013; Safaie et al., 2013; Zairion et al., 2014).

Egg diameter was found ranged 300-420 μm, showing smaller size than previous reports (Soundarapandian and Tamizhazhagan, 2009; Ikhwanuddin et al., 2011, 2012a; Safaie et al., 2013). The volume of egg was also smaller than that reported by Ravi and Manisseri (2013). However, the pattern of change in the size and color of the eggs during embryo development was identical to the previous studies (Arshad et al., 2006; Soundarapandian and Tamizhazhagan, 2009; Ikhwanuddin et al., 2011, 2012a; Ravi and Manisseri, 2013; Safaie et al., 2013). The diameter and volume of eggs during embryonic development characterized by changing from yellow to dark gray increased 25.16% and 91.76%, respectively. The increase in the egg volume, ranged from 46.52% to 75%, was higher than previous reports (Ravi and Manisseri, 2013), whereas the increase in its wet weight in the present study (36.35%) was lower.

The increase in size of the crab eggs is probably due to an increase in size of the embryo, the absorption of water through the membrane of the egg, and water retention resulting from respiration and fat metabolism (Figueiredo and Narciso, 2008; Ravi and Manisseri, 2013), which are not uncommon phenomena in the Brachyura (Figueiredo and Narciso, 2008). It was also reported that significant increase in wet weight, diameter, and volume of crab eggs is occurred on the seventh and eighth day during incubation period or two days before the end of embryonic development (Ravi and Manisseri, 2013). Eggs of the blood-spotted swimming crab, *Portunus sanguinolentus*, were also reported to change in diameter during embryonic development, i.e., from 260.16 μm at stage 1 to 290.2 μm and 340.32 μm at stages 2 and 3, respectively (Soundarapandian et al., 2013).

As conclusions, Ovigerous blue swimming crabs, *Portunus pelagicus*, with yellow to dark gray eggs showed a wide habitat distribution from shallow to deeper water. A large degree of variation in body size was detected in ovigerous female crabs collected from various types of habitat with different levels of embryonic development. The wet weight, diameter, and volume of the eggs increased with color change as an indicator of embryonic development, but the dry weight decreased.

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