Indian Journal of Science and Technology, *Vol 8(7), 596–607, April 2015*

ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Sexual Maturity, Reproductive Pattern and Spawning Female Population of the Blue Swimming Crab, *Portunus pelagicus* (Brachyura: Portunidae) in East Lampung Coastal Waters, Indonesia

Zairion*, Yusli Wardiatno and Achmad Fahrudin

Bogor Agricultural University, Indonesia; zairion.zai@gmail.com, yusli@ipb.ac.id, fahrudina@ipb.ac.id

Abstract

Little is known about the biology of the blue swimming crab, *Portunus pelagicus* in east Lampung coastal waters, Indonesia; despite in fishery point of view this species has valuable contribution to the country. We examined the gonad development and the occurrence of ovigerous females for determining the mean size at sexual maturity, reproductive pattern and spawning female population of the crab in East Lampung coastal waters. The mean size of males and females reached sexual maturity (Lm_{50}) at 98-mm and 103-mm carapace width (CW), respectively. Reproductive pattern was partially spawners, seasonal-continuous throughout in the year with the peak spawning and breeding in April to June and October to November. Most female at the size >111-mm CW showed double breeding in a season. The relative percentage of all ovigerous females below the size of Lm_{50} was considerably low (±2%), spawning female population at 103–170.9-mm CW size range and the ratio of ovigerous to adult females above the average value found in 116-165.9-mm CW size range. Using 115-mm CW as minimum legal size would conserve ±21.38% spawning female as breeding population.

Keywords: Physiological Maturity, *Portunus pelagicus*, Reproductive Periodicity, Spawning Female Population, Indonesia

1. Introduction

The blue swimming crab, *Portunus pelagicus* "sensu lato" occurs in shallow tropical and temperate coastal and estuarine waters throughout the Indo-West Pacific, while *Portunus pelagicus* (Linnaeus, 1758) "sensu stricto" is distributed across Southeast and East Asia[1]. The abundance of this species in nature combined with increasing demand renders it as valuable target in fishery sector throughout its distribution area. In Indonesia, *P. pelagicus* is exploited by small-scale fishery in most coastal waters and wild catch production tends to increase in the decade. Data in 2011 shows that the total capture was approximately 42,410 tons and *P. pelagicus* of the East Lampung coastal waters contributed approximately 21%. Most of catches are used in crab meat industry and then exported by the retailer[2].

Reproductive biology of a species is one of the most studied topics on life histories, and analysis is mainly focused on some of life history traits, *i.e.* size and age at maturity, size and age-specific reproductive investment[3,4], and other reproductive biology attributes, *i.e.* mating, spawning time, duration, and spawning population[5,6]. In fishery point of few, understanding on reproductive biology characteristics are important for sustainable management, especially for harvesting strategy of exploited populations[7-11] or for assessing the efficacy of fishery regulations[12]. Sexual maturity and other reproductive biology characteristics of P. pelagicus have been studied throughout its distribution area, e.g. in India waters[13-17], in

*Author for correspondence

Philippines[18,19] and in Malaysia[20,21]. However, reproductive biology parameters seemed to have intra and interspecific variations, area-specific and regional differences. In most earlier studies, estimation of body size at sexual maturity of male and female in brachyuran crabs were usually determined by physiological maturity based on gonad condition[22] or functional maturity related to allometric changes in growth of the body parts[14,23-25] or both[26-30]. A synchronous of physiological and functional maturity was found in females when studied by both approaches, but some asynchrony occured in males. Therefore, physiological maturity is often used to determine the size at sexual maturity of females portunid crabs, since there is an actual capacity to release gametes and correspond to functional maturity[22]. In addition, morphometric maturity does not always indicate functional maturity[31] or does not coincide with physiological sexual maturity[32].

Brachyuran crabs are categorized as iteroparous species which have high variations of reproduction patterns[33,34]. The reproductive periodicity of *P. pelagicus* follows a continuous pattern in tropical and subtropical region[18,35]. When duration, occurrence, and intensity of reproduction are taken into account, the reproduction periodicity may be subdivided into three categories[36]: (1) seasonal reproduction, either the presence of the females with mature gonad or the presence of ovigerous female are restricted to a certain months or seasons; (2) continuous, when ovigerous females occur during all months of the year with similar frequency; (3) seasonal-continuous, the presence of ovigerous female in all months of the year, but with distinguishable peak of high occurrence in some months or seasons.

Little is known about biology of *P. pelagicus* in East Lampung coastal waters and there have been no studies on its reproductive biology, although it supports substantial artisanal fisheries. The aims of this study were to determine sexual maturity in the term of the size at which 50% of the population is physiologically mature, reproductive pattern based on gonad condition (including ovigerous female and its occurrence) and spawning female population of *P. pelagicus* in East Lampung coastal waters. The use of those reproductive biology characters in fisheries management is highlighted.

2. Materials and Methods

2.1 Samples Collection and Environmental Regimes

In order to determine the size at sexual maturity and reproductive pattern, *Portunus pelagicus* samples were collected monthly from June 2011-May 2012 at two landing sites, *i.e.* Kuala Penet and Labuhan Maringgai, East Lampung District, Lampung Province, Indonesia (Figure 1). Those samples represent different fishing ground (*i.e.* near shore and offshore), which captured by local fisher using set gill-net as main fishing gear, nets had mesh sizes of 3.0-4.5 in or 7.6-11.4 cm[37]. The proportion of landed crabs (males, ovigerous females and non-ovigerous females) from representative fishing ground was recorded daily during a week in each month. Sexes were determined by examining of morphological characteristics of species. Meanwhile, male and female non-ovigerous samples of representative size distributions were collected by stratified random sampling based on landing sited and fishing ground. This method provides wider size range of captured crabs and potentially less bias in estimating of size at sexual maturity. Collected samples were also represent small capture size and immature females, indicated by triangular shape of abdominal flap and tightly fix to the cephalothorax[38,39]. In addition, ovigerous females (egg bearing females) were also taken in various sizes for ovaries examinations. All samples were measured their carapace width (CW: the distance between tips of 9th anterolateral teeth), carapace length (CL: distance between the frontal marginal to the posterior margin of the carapace), and body weight (W). Length measurement were done by using digital calliper to the nearest 0.01 mm, while W was measured to the nearest 0.1 g by using digital balance.

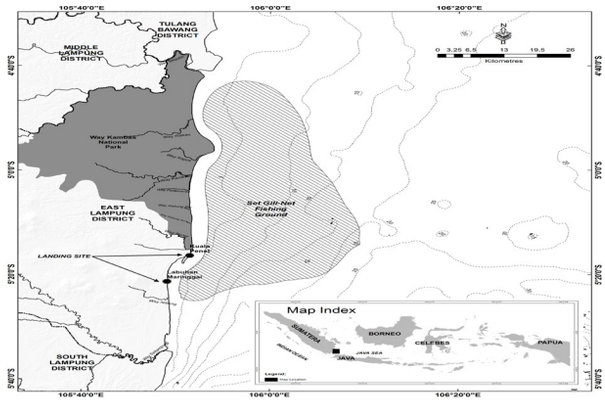

Figure 1. Map showing the East Lampung coastal area as well as crabs fishing ground by using set gill-net in coastal waters and sampling location at landing site.

Gonad examination was conducted after morphological characteristic measurements. In order to determine the spawning female population, the size distribution frequency data from independent monthly collection using the same type of fishing gear from March 2012–February 2013 was also included (Zairion *et al*. unpublished data).

The East Lampung coastal land area is covered by approximately 60% of low land forest and protected as Way Kambas National Park (WKNP). There is no sea grass bed found in the shallow coastal waters, but this area is one among the blue swimming crab habitats and fishing ground of Indonesia. Based on water quality checking in February and August as a representative of rainy season (west and north west monsoon) and dry season (east and south east monsoon), there was no high variation of sea surface temperature (28–32°C). Meanwhile, near bottom temperature for both season ranged between 28–29.5°C. On the other hand, sea surface salinity ranged between 10–25 PSU from near shore to offshore at northern area in February due to high freshwater supply from Way Seputih River and 25–29 PSU at the bottom. At the same time, sea surface and bottom salinity were 29–30 PSU and 30–32 from near shore to offshore at southern area (close to Labuhan Maringgai). In contrast, salinity for both surface and bottom became 17–27 and 27–30 PSU at northern during dry season, and 28–32 and 29–32 PSU at southern, respectively.

2.2 Gonad Examination and Gonad Somatic Indices (GSI)

The female maturity stages in portunid crabs recognized by different researchers concerning the maturation of female ovaries in terms of morphological or histological feature show variation. Similar thing is shown in male vas differentia. In this study, maturity stages of female gonad were determined by classifying them into four categories, *i.e*. Stage I (immature), stage II (early development), stage III (late development or maturing), stage IV (fully mature). Whilst male gonad maturity stages were classified into three categories, *i.e*. Stage I (immature), Stage II (maturing), and Stage III (mature)[29,40,41]. In addition, three classifications were used for embryonic development stages, namely: (i) initial (yellow, orange–yellowish), (ii) intermediate (brownish–brown), and (iii) final (black–grey black)[21,36]. Prior to measurement of gonad somatic indices (GSI), all part of individual gonad was taken carefully by blunt-nosed thumb forceps with serrated tips and the weight was measured to the nearest 0.001 g using electronic balance.

2.3 Data Analysis

2.3.1 Sexual Maturity and Gonad Somatic Indices

The proportion of matured gonad was used in determining size at sexual maturity and internal ovarian of ovigerous females were excluded[7]. The size at which 50% (Lm_{50}) of crabs were considered sexually matured by fitting a logistic regression curve to the proportion of mature gonad females for each sequential 5-mm CW size class, following the method as described by King[42]. Gonad somatic index (GSI) for males, females and ovigerous females was also analysed[6,40,41]. A trend analyses and one way ANOVA[43] were used to test differences of GSI for males, females, and ovigerous female by time and size.

2.3.2 Reproductive Pattern and Spawning Female Population

Reproductive pattern for both spawning and breeding season was determined by temporal distribution of mature female gonad, GSI, and the proportion of ovigerous to the adult females[6,25,29,44,45]. A trend analysis were used for the temporal GSI and the proportion of ovigerous and completed by the one way ANOVA test to describe any differences. Analysis of reproductive pattern was also completed by gonad condition of ovigerous female. Meanwhile, we propose the spawning female population by estimated the relative percentage of adult females and ovigerous in each 5-mm CW size class, as well as their ratio.

3. Results

3.1 Crabs Size, Gonad Development and Sexual Maturity

TA total of 1297 specimens were collected during observation period, while the size of males was wider than females and ovigerous (Table 1). The relationship between the CW and CL of males and females was $CL_M = 0.5039$ CW-5.7016 ($n= 545$, $R^2 = 0.99$, $p< 0.05$) and $CL_F = 0.4895$ CW-4.9784 ($n= 485$, $R^2 = 0.99$, $p< 0.05$), respectively. All of males and females in the below 81-mm CW found to have gonad development stage I, while the size attained maturity (stage III) found in the size class 86.0–90.9-mm

CW and fully mature gonad female (stage IV) found in the size class 91–95.9 mm CW. The mean size at which 50% of males and females reached maturity (Lm_{50}) with 95% confidence interval (CI) was 98±0.2-mm and 103±0.1-mm CW (Figure 2), corresponding to 44 and 46-mm CL. In addition, the mean size at which 95% of males and females became mature was approximately at 124 and 126-mm CW, respectively.

Matured males could be obtained in all sampling month and the estimated proportion approximately 38.6–72.0% (53.0%±3.3SE) as well as female gonad stage of IV approximately 10.8–32.6% (20.0±2.3SE). The proportion of matured gonad in female were prevalent high (28.2–32.6%) during March to June and also in November (20%), but it was considerably low (10–13%) in July to August (Figure 3). This study also demonstrated great variations

Table 1. Body size description of each category or sex of *Portunus pelagicus* samples in East Lampung coastal waters and the numbers in parentheses refers to the average ±SD, des

Category or Sex	Number (ind.)	CW (mm)	CL (mm)	W (g)
Male (M)	545	71.27-181.17 (119.88±19.86)	30.62-84.74 (54.70±10.08)	34.2-460.1 (138.83±74.68)
Female non-ovigerous (F)	485	74.12-173.21 (117.38±19.23)	31.52-80.39 (52.48±9.48)	31.4-341.9 (118.58±58.76)
Ovigerous female (OVI)	267	91.58-168.00 (127.44±15.76)	40.55-79.30 (58.11±8.49)	78.1-387.5 (173.24±68.87)

Note: CW = carapace width, CL = carapace length, W = body weight

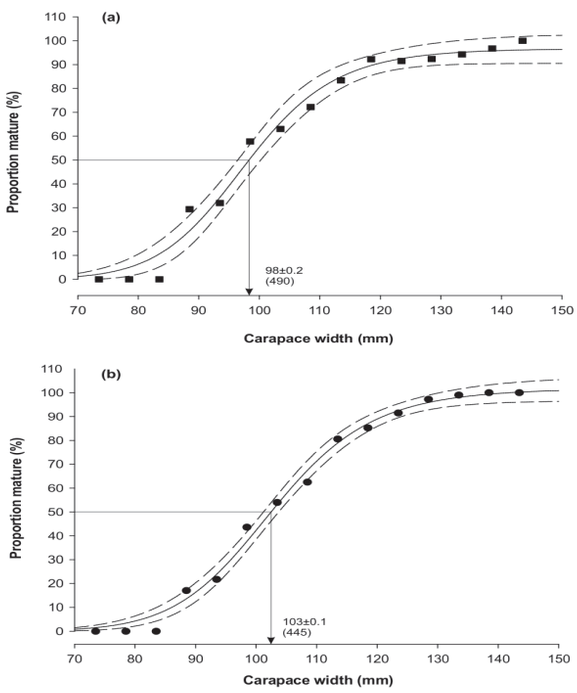

Figure 2. Logistic curve and their 95% confidence limits showing the proportion of mature gonad of *Portunus pelagicus* in each carapace width ranges; (a) males, (b) matured females; arrows denote L_m50's and the numbers in parentheses refer to the number of crabs used to establish the regressions.

on the internal ovarian of ovigerous female (OVI) in all classification of embryonic development stages (Figure 4). Although, ovigerous female gonad was dominated by stage III, but gonad stage of IV was approximately found to be 7.7–21.6% (13.4±4.2SE) in all of embryonic development stages (Figure 5).

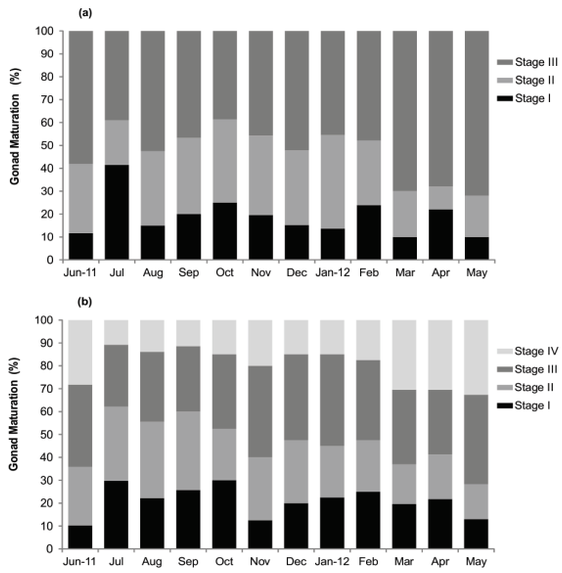

Figure 3. The proportion of gonad maturity stage of *Portunus pelagicus* in each month: (a) males and (b) females.

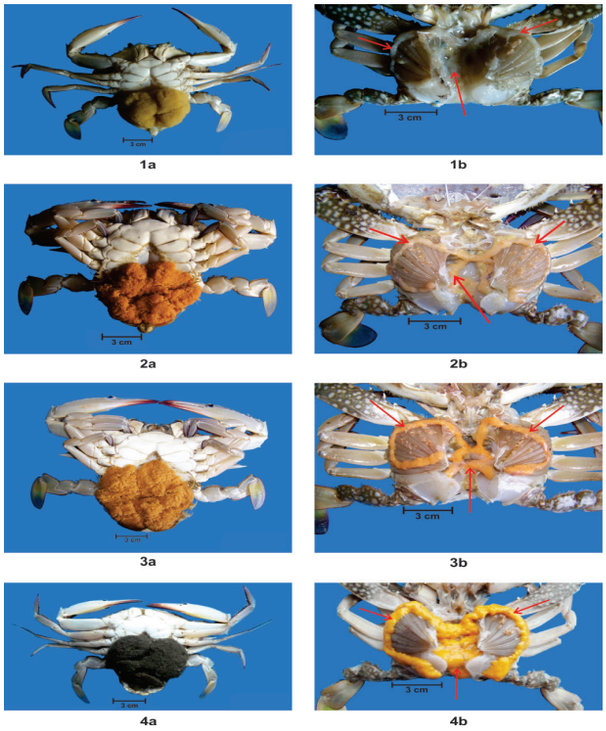

Figure 4. Internal ovarian of ovigerous female in various stages of maturity and arrows denoted the gonad condition in its body cavity and hepatopancreatic region; The different colour of egg mass attached on female abdomen flap (1a to 4a) did not indicate their influence to variation in gonad maturity stage (1b to 4b).

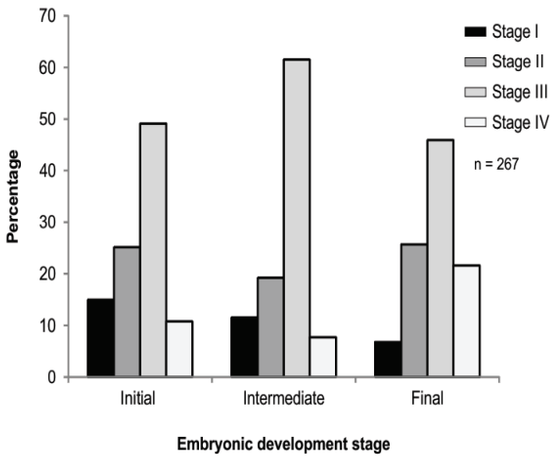

Figure 5. The relative occurrence of gonad development stage (stage of I to IV) of ovigerous female in each embryonic development stages.

3.2 Gonad Somatic Indices

The gonad condition patterns is expressed by gonad somatic index (GSI). Mean monthly of all female GSI showed slightly cyclic pattern throughout the year, increase progressively from 1.60% in January to a maximum of 2.50% in May and subsequently decreased to minimum of 1.53% in July, and then became increased again to 2.30% in November (Figure 6). The mean monthly GSI of matured females also exhibited cyclic pattern. It was prevalent during April to July (3.3%±0.5 to 3.6%±0.9SE) and September to December (3.3%±0.3 to 4.0%±0.3SE). There were significant difference ($p<0.05$) of females GSI in the observed period. However, the gonad index of males did not show significantly different; it would therefore not to be discussed further.

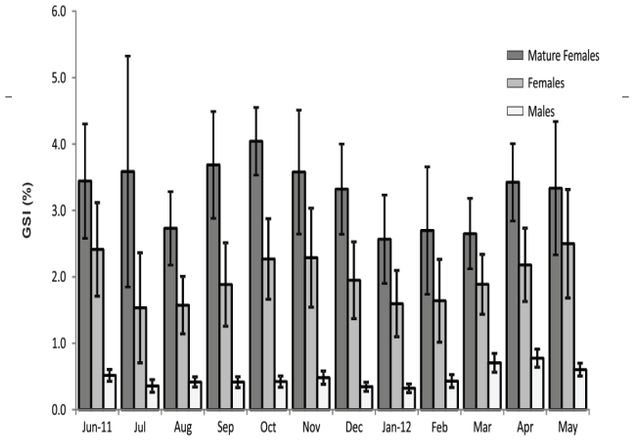

Figure 6. Mean value of gonada somatic index (GSI) and their 95% confidence limits of males, female non-ovigerous and matured females of *Portunus pelagicus* in each month.

The mean monthly GSI of all ovigerous females found more cyclic than non ovigerous ones, which the percentage was 0.82±0.18SE in June to 3.88±0.45SE in November and there were significant different ($p<0.05$) among ovigerous females GSI thorough observed month. The highest mean GSI of matured ovigerous females was found in July to August and October to December (Figure 7). Ovigerous female with gonad development at stage IV was found in the size class 111.0–115.9-mm CW and bigger, while the mean GSI was 1.2–4.8% in each size class which might indicate the ocurrence of double breeding.

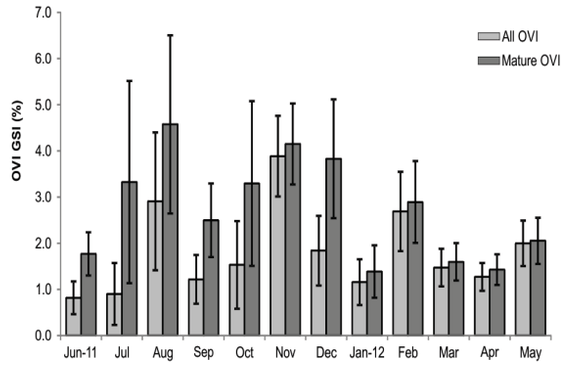

Figure 7. Mean value of gonad somatic index (GSI) of all ovigerous (All OVI) and mature ovigerous female (mature OVI) of *Portunus pelagicus* and their 95% confidence limits in each observed month.

3.3 Temporal Proportion of Ovigerous Females

Ovigerous females found in all sampling months and their monthly proportion to the adult females showed cyclic pattern with most prevalent in April to June and October to November, indicated as seasonal continuous reproduction pattern (Figure 8). These proportion for both by the number and weight ranged between 5.2–19.6% (10.4±0.4SE) and 6.4–25.5% (14.2±0.5SE) and there were significantly different ($p<0.05$) in all observed months.

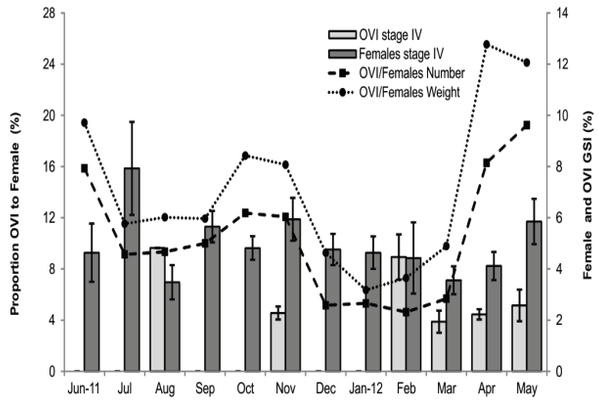

Figure 8. Temporal proportion of ovigerous to adult females *Portunus pelagicus* (%) for both by number and weight of captured crabs, and their GSI for the gonad stage IV, which indicates of spawning and breeding pattern.

3.4 Spawning Female Population

Female with gonad stage IV as well as the smallest size of ovigerous female were available since the size class 91–95.9-mm, pronounced spawning and breeding activity began at this size class to at least in the size class 166–170.9-mm CW. The relative percentage of ovigerous females in each 5-mm CW size class increased from the lowest of 0.28% in the size class 91–95.9-mm CW to the highest of 12.94% in the size class 126–130.9-mm CW, and then decreased again. Meanwhile, the relative percentage of all ovigerous female in the size below Lm_{50} (*i.e.*, 91–102.9-mm) was approximately 2%. The ratio between ovigerous females to the adult females was increasing from the lowest of 0.01 in the size class 91–95.9-mm to the highest of 0.36 in the size class 151–155.9-mm CW, and then decreased. The average ratio was 0.17±0.02SE and the ratio above of the average value found in the size between 115–165.9-mm CW (Figure 9), while the relative percentage of all ovigerous females less than 115-mm CW was approximately 21.38%.

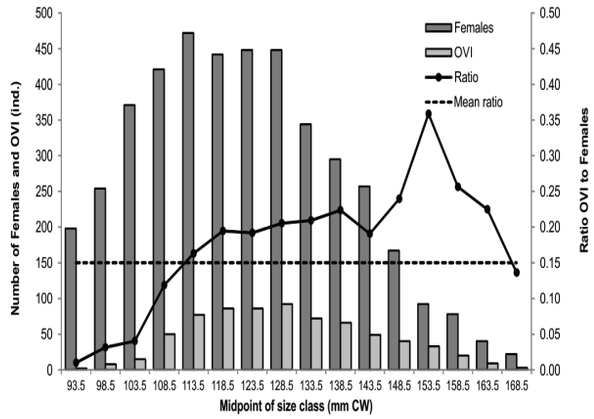

Figure 9. Number of captured ovigerous (OVI) and adult females *Portunus pelagicus* and its ratio in each 5-mm CW size class.

4. Discussion

4.1 Sexual Maturity

Our results show that males and females were almost synchronous in gonad maturity and this strategy is believed as natural process of maintaining the population size, providing large numbers of adult crabs, and maximizing reproductive effort related to their habitat[36]. Based on gonad development, both sexes below 81-mm CW size

were all immature and a *priori* as juvenile, whilst adolescent females in the size above 91-mm CW since they have capability in extruding egg[7], while fully adult for males and females approximately in the size above 124-mm and 126-mm CW, respectively. This finding corresponds to the *P. pelagicus* in southwest coast of India where size <80-mm CW was categorized as juvenile[6] and in Moreton Bay of Australia where the sexually matured crab was considered above 90-mm CW[35].

Our estimated for the Lm_{50} of female *P. pelagicus* was slightly different with some estimates in some other coastal waters of Indonesia, *i.e.* 105-mm CW in northern West Java[46], 48-mm CL or 101.40-mm CW in Central Java[47] as well as in Ragay Bay, Philippines, *i.e.* 105-mm CW[19], but it was much different to many other areas (Table 2). This discrepancy might reflect of disparate in biology of the species and genetic composition[33,45]. The same species in the same area or in different area might also vary in the Lm_{50} since pubertal occurred over wide size range[14], which is related to variation in environmental conditions, i.e. food abundance, population density and parasitism[7,34,48]. Environments with abundant food allow individuals to grow faster and larger. By taking the maturity size of the crab, it can be said that East Lampung coastal waters might provide sufficient food and other favourable environments compared to coastal waters in northern West Java and Central Java of Indonesia.

Other factor which might influence in maturity size of the species was fishing intensity because it may diminish the density of the species[49-50]. Fishing ground or site of sampling (*i.e.* estuary versus offshore) may also influence the estimation of mean size at maturity of female *P. pelagicus* due to emigration habit of matured females from estuaries to offshore[29,45,51]. In addition, fishing gears may have also effect the differences in estimated Lm_{50} related to their selectivity, *i.e.*, traps catches are often biased for determining sexually matured crabs[39]. Fishing intensity in the study area is not known well yet; however, our samples were collected in representative of all fishing ground, as well as in all season. The crabs were also captured by the fisher using set gillnet with the mesh size of 7.6-11.4 cm and it seems to be a low selective fishing gear. Moreover, the Lm_{50} may also vary as consequent of interspecific reproductive biology pattern[33]. In terms of reproductive biological characters, the crab in the study area might be different to the species in Karnataka, including in Persian Gulf and Bardawil lagoon of Egypt as well as the species in sub-tropical and temperate regions of Australia (Table 2).

The estimated Lm_{50} of female *P. pelagicus* was also comparable to the smallest size of ovigerous female since the proportion of ovigerous that has been used also to determine the size at functional sexual maturity in crabs[7,31] and lobster[52]. Other research reported that the female Lm_{50} of *P. pelagicus* in Karnataka waters was 99-mm CW[6], whiles the smallest ovigerous female has had carapace width 89-mm CW and it possibly occurred for few females to spawn under the size of Lm_{50}. In particular, almost all of the small size ovigerous female below Lm_{50} found in September to November, while this period represents late dry season in western part of Indonesia. During dry season, sea surface and bottom temperature were relatively high in East Lampung coastal waters (*i.e.* the average 29-32°C and 28-29.5°C), which might induce of early gonad maturation and spawning in the next consecutive month[29,44,49,53].

4.2 Reproductive Pattern and Spawning Female Population

Analysis of *P. pelagicus* reproductive pattern in this study was furnished by the supplementary evidence concerning the occurrence of ovigerous female and their ovarian conditions. This method has additional advantages in of investigation of the spawning or breeding season[14,56]. Our result showed that P. pelagicus in East Lampung coastal waters was capable for continuous spawning throughout the year. However, the peak of spawning and breeding season seems to occur in April to June and October to November (Table 2). Indeed, the peak of breeding period also coincided with the period of high GSI's gonad stage IV for both females and ovigerous (Figure 8). The occurence of high GSI of female gonad stage IV as well as ovigerous females GSI stage IV in certain months seems not to be overlapped to the high proportion of ovigerous females. They might spawn during our interval observation period or in the next consecutive month, or they migrate to deeper water for spawning.

Reproduction period of *P. pelagicus* in the study area had two peak season (seasonal-continuous), which supports the other previous observations in tropical and subtropical region[18,35,55]. Various results in reproduction period was shown, *i.e.* thorough in the year and peaks season at the first and last quarters[18], or in February to April and July to October19 (Table 2). It was concluded

Table 2. Comparative findings of the size at sexual maturity and spawning season of blue swimming crab, *Portunus pelagicus* in Indonesia (1-3), other tropical (4-7); subtropical and temperate region (8-14)

No.	Location	Maturity size, Lm_{50} (CW or CL)		Peak season in:		Ovigerous female size (mm)	Source
		Male	Female	Gonad condition	% Ovigerous		
1.	East Lampung (Western Java Sea)	98-mm CW	103-mm CW	Mar-Jun & Sep-Nov	Apr-Jun & Oct-Nov	91.58-168.00 CW	Present study
2.	Brebes, Central Java	63-mm CL or 128-mm CW	48-mm CL or 101.4-mm CW	Jan-Mar & Jun-Aug	Apr & Sep	-	47
3.	Subang, West Java*)	101.3-mm CW	105-mm CW	-	-	89-156 CW	46
4.	Serawak, Malaysia	85-mm CW	95-mm CW	-	-	144-193 CW	20
5.	Ragay Bay, Luzon, Filipina	-	105-mm CW	Feb-Apr & Jul–Oct	-	-	19
6.	Karnataka, SW coast India**)	-	96-mm CW	Feb-Mar	-	-	54
7.	Southwest coast, India**)	105-mm CW	99-mm CW	Jan-Feb & Sep	Mar-May	89-170 CW	7
8.	Persian Gulf and Oman Sea**)	-	113-mm CW	-	Sep & Oct	103-155 CW	55
9.	Southeast Australian Estuary**)	-	46-mm CL	Nov-Dec	Nov-Jan	55-80 CL	45
10.	Leschenault Estuary, SW Australia**)	88.3-mm CW	98-mm CW	Sep-Nov	Dec	-	29
11.	Koombana Bay, SW Australia**)	88-mm CW	86.9-mm CW	Oct	Nov-Dec	-	29
12.	Peel-Harvey Estuary, SW Australia**)	86.5-mm CW	97.5-mm CW	Nov	Nov	-	29
13.	Cockburn, SW Australia**)	88.4-mm CW	86.4-mm CW	Sep	Oct-Dec	84-154 CW	29
14.	Shark Bay, SW Australia**)	97-mm CW	92-mm CW	Aug-Sep	Aug	-	29

Note: *) = Reanalyzing by the authors using logistic regression curve; **) = According to Lai et al.1, the blue swimming crabs of the western Indian Ocean, that is from Pakistan throughout Arabian Sea, Persian Gulf, Egypt, and Tanzania referred to *Portunus segnis*; and another from Western, Southern, and South eastern of Australian referred to *Portunus armatus*.

that peak of spawning or breeding season varied in different places and might relate to favourable environmental condition prevailing in that period, i.e., temperature, salinity, rainfall, food availability, and predators36. The other seasonal-continuous pattern in breeding season of other portunid crabs species in tropical and sub-tropical area were also found, *i.e. Arenaeus cribrarius* in Ubatuba SP, Brazil[36] and *P. spinimanus* in Ubatuba SP, Brazil[57] .

The evidence in varieties of gonad stages of ovigerous females at all embryonic development stages make the females able to produce multiple spawning, and capable of producing more than one brood of eggs in the same season. Female blue crab (*Callinectis sapidus*) had "partially synchronous" in oocyte development stages in most ovarian lobe as well as inter ovarian lobe and individual female, make it became multiple spawning[58]. In addition, It was proved that this capability could be up to 3 broods of eggs and would be size-dependent within the species, *i.e.* above 110-mm CW[29,59] and above 55-mm CL[45]. Our finding exhibited that the double breeding in a season seemed to be occur in most female at the size above 111-mm CW, since they had gonad at development stage IV.

Although, spawning is the process of releasing the eggs and sperm, while breeding is the process of releasing the offspring, however, the extrusion of eggs by female crabs could be referred also to the spawning[60], since fertilization has occurred externally. Thus, the relative occurrence of ovigerous female over the size might notably as breeding population[6,18,25]. Despite of our study showed that spawning and breeding female population tended to start in the same size (*i.e.* above 91-mm CW), yet the relative percentage of ovigerous female was considerably the lowest in the size class 91–95.9-mm CW (*i.e.* 0.28%) as well as the ratio of ovigerous females to the adult females (*i.e.* 0.01). Similarly, all of ovigerous females in the size below Lm50 (*i.e.* 91.0–102.9-mm CW) was approximately 2% and their ratio value was 0.04 (Figure 9). Therefore, the breeding female population was at 103–170.9-mm CW size range.

4.3 Recommendation for Crab Fishery Management

Management option by size-based limit to harvest strategy has been usually implemented in crustacean fishery[61]. Some protection may be given to the spawning potential and reproductive capacity of the stock to ensure that a few small adult crabs are caught, and permit them to spawn at least once before they become vulnerable to fishing. However, "spawn at least once policy" may crabs stock resilience become low and is easy to collapse[61,62].The common policy in fishery management to protect a target population for its sustainable use is minimum legal size (MLS)[63]. MLS might be set up at the Lm_{50} as limit reference point (LRP) in precautionary approach (PA) and the size could be increase 10% as target reference point (TRP) when fishing rate was increase. Figure 9 shows the ratio of all ovigerous females to adult female was low at the size class below the Lm_{50}. Thus, MLS at the Lm_{50} seems not to meet a properly sufficient protection to spawning female population for sustainable use of crab resource in the study area. In addition, regulation based on cut-off sizes (Lm_{50}) seems to be not an appropriate management strategy[64]. Therefore, recommended MLS for the *P. pelagicus* fishery in East Lampung coastal waters would be greater than Lm_{50} and is proposed at the size 115-mm CW. At this size, the ratio of ovigerous females to adult females was in average value, meaning that the spawning female in population would become breeding population approximately 21.38% and would be an appropriate precautionary approach for spawning and breeding female population in maintaining stock productivity.

5. Conclusion

The mean size at which 50% of males and females reached physiological maturity (Lm_{50}) was 98±0.2-mm and 103±0.1-mm CW, respectively; thus, it is relatively different to those of the same species in other areas. Reproductive pattern was partially spawners, seasonal-continuous throughout in the year. The peak of spawning and breeding season was in April to June and October to November. Double breeding in a season seemed to occur in most females at the size larger than 111-mm CW. The relative percentage of all ovigerous females below the size of Lm_{50} was considerably low (±2%) and spawning female population in the size 103–170.9-mm CW. The spawning female under the size 115-mm CW would be approximately 21.38% of breeding population. The size is proposed to be the Minimum Legal Size for the crab fishery sustainable use.

6. Acknowledgement

This work is funded partially by the Directorate General

of Higher Education, Ministry of Education and Culture of Indonesia and by the Indonesia Blue Swimming Crab Management Association (APRI) in form of collaborative research with Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University (IPB), Indonesia. The authors are thankful to Professor Mennofatria Boer for his valuable input and Professor Makoto Tsuchiya (Japan) for his constructive comments; some of graduate bachelor students and technicians for their assistance during field and laboratory work. We thanks also to David Harris and Daniel Johnson (Australia) for their literature support.

7. References

1. Lai JCY, Ng PKL, Davie PJF. A revision of the *Portunus pelagicus* (Linnaeus, 1758) species complex (Crustacea: Brachyura: Portunidae), with the recognition of four species. RBZ 2010; 58(2):199–237.
2. Capture fisheries statistics of Indonesia year 2011. Jakarta (ID): Directorate General of Capture Fishery- Ministry of Marine Affair and Fishery of Indonesia; 2012.
3. Stearns SC. Life-history tactics: A review of the ideas. The (Q Rev Biol).1976; 5(1):3–47.
4. Stearns SC. Essay Review: Trade-offs in life-history evolution. Funct Ecol. 1989; 3(3):259–68.
5. Robertson WD, Kruger A. Size at maturity, mating and spawning in the portunid crab *Scylla serrata* (Forskal) in Natal, South Africa. Estuar Coast Shelf Sci. 1994; 39(2):185–200.
6. Sukumaran KK, Neelakantan B. Spawning biology of two marine portunid crabs, P*ortunus (Portunus) sanguinolentus (Herbst)* and *Portunus (Portunus) pelagicus* (Linnaeus) from the Karnataka Coast. The Fourth Indian Fisheries Proceeding, 24-28 November 1996; Kochi, India: 1999; p. 35–8.
7. Campbell A, Eagles MD. Size at maturity and fecundity of rock crabs, Cancer irroratus, from the Bay of Fundy and south western Nova Scotia. FB. 1983; 81(2):357–62.
8. Addison JT, Bennett DB. Assessment of minimum landing sizes of the edible crab, Cancer *pagurus L*. on the east coast of England. Fish Res. 1992; 13(1):67–88. doi:10.1016/0165-7836(92)90034-Q.
9. Ungfors A. Sexual maturity of the edible crab (*Cancer pagurus*) in the Skagerrak and the Kattegat, based on reproductive and morphometric characters. ICES Journal of Marine Science. 2007; 64:318–27.
10. Morgan MJ. Integrating reproductive biology into scientific advice for fisheries management. Journal of Northwest Atlantic Fisheries Science. 2008; 41:37–51. doi:10.2960/J.v41.m615.
11. Udoh JP, Nlewadim AA, Ofor C. Maturity estimation in male swimming brachyuran crab, *Callinectes amnicola* (De Rocheburne, 1883) (Decapoda , Portunidae) in the imo river estuary, Nigeria. NJAFE. 2009; 5(2-4):61–71.
12. Gerhart SD, Bert TM. Life-history aspects of stone crabs (Genus *Menippe*): Size at maturity, growth, and age. Journal of Crustacean Biology. 2008; 28(2):252–61.
13. Pillay KK, Nair NB. The annual reproductive cycles of *Uca annulipes, Portunus pelagicus* and *Metapenaeus affinis* (Decapoda: Crustacea) from the South-west coast of India. Marine Biology. 1971; 11(2):152–66.
14. Sukumaran KK, Neelakantan B. Relative growth and sexual maturity in the marine crabs, *Portunus (Portunus) sanguinolentus* (Herbst) and *Portunus (Portunus) pelagicus* (Linnaeus) along the southwest coast of India. Indian J Fish. 1996; 43(3):215–23.
15. Sukumaran KK, Neelakantan B. Sex ratio, fecundity, reproductive potential of two marine portunid crabs, *Portunus (Portunus) sanguinolentus* (Herbst) and *Portunus (Portunus) pelagicus* (Linnaeus), along the Karnataka coast. Indian J Mar Sci. 1997; 26:43–8.
16. Sukumaran KK, Neelakantan B. Maturation process and reproductive cycle in two marine crabs, *Portunus (Portunus) sanguinolentus* (Herbst) and *Portunus (Portunus) pelagicus* (Linnaeus) along the Karnataka coast, India. Indian J Fish. 1998; 45(3):257–64.
17. Sahoo D, Panda S, Guru BC. Studies on reproductive biology and ecology of blue swimming crab, *Portunus pelagicus* from Chilika Lagoon, Orissa, India. Journal of the Marine Biological Association of the United Kingdom. 2011; 91(1):257–64. doi: 10.1017/ S0025315410000354.
18. Batoy CB, Sarmago JF, Pilapil BC. Breeding season, sexual maturity and fecundity of the blue crab, *Portunus pelagicus* L. in selected coastal waters in Leyte and vicinity, Philippines. ATR. 1987; 93:157–77.
19. Ingles JA, Bkaum E. Reproduction and larval ecology of the blue swimming crab, *Portunus pelagicus*, in Ragay Gulf, Philippines. Internationale Revue der gesamten Hydrobiologie und Hydrographie. 1989; 74(5):471–90. doi:10.1002/iroh.19890740503
20. Ikhwanuddin M, Shabdin ML, Abol-Munafi AB. Size at maturity of blue swimming crab (*Portunus pelagicus*) found in Sarawak Coastal Waters. JSSM. 2009; 4(1):56–68.
21. Ikhwanuddin M, Azra MN, Siti-Aimuni H, Abol-Munafi AB. Fecundity, embryonic and ovarian development of blue swimming crab, *Portunus pelagicus* (Linnaeus 1758) in coastal waters of Johor, Malaysia. Pakistan J Biol Sci. 2012; 15(15):720–28. doi:10.3923/pjbs.2012.720.728.

22. Castiglioni DS, Negreiros-Fransozo ML. Physiologic sexual maturity of the fiddler crab *Uca rapax* (Smith, 1870) (Crustacea, Ocypodidae) from two mangroves in Ubatuba, Brazil. An International Journal of Brazilian Archives of Biology and Technology. 2006; 49(2):239–48.
23. Gonzalez-Gurriaran E, Freire J. Sexual maturity in the velvet swimming crab *Necora puber*: Morphometric and reproductive analyses. ICES Journal of Marine Science. 1994; 51:133–45.
24. Hall NG, Smith KD, de Lestang S, Potter IC. Does the largest chela of the males of three crab species undergo an allometric change that can be used to determine morphometric maturity? ICES Journal of Marine Science. 2006; 63:140–50.
25. Rasheed S, Mustaquim J. Size at sexual maturity, breeding season and fecundity of three-spot swimming crab *Portunus sanguinolentus* (Herbst, 1783) (Decapoda, Brachyura, Portunidae) occurring in the coastal waters of Karachi, Pakistan. Fish Res. 2010; 103:56–62. doi:10.1016/j.fishres.2010.02.002.
26. Pinheiro MAA, Fransozo A. Sexual maturity of the speckled swimming crab *Arenaeus cribrarius* (Lamarck, 1818) (Decapoda, Brachyura, Portunidae), in the Ubatuba littoral, Sao Paulo State, Brazil. Crustaceana. 1998; 71(4):434–52.
27. Muino R, Fernandez L, Gonzalez-Gurriaran E, Freire J, Vilar JA. Size at maturity of *Liocarcinus depurator* (Brachyura: Portunidae): A reproductive and morphometric study. JMBA. 1999; 79(2):295–303.
28. Potter IC, de Lestang S, Melville-Smith R. The collection of biological data required for management of the blue swimmer crab fishery in the central and lower west coasts of Australia. Murdock University; Perth (AU): Fisheries Research and Development Corporation (FRDC) Report; 2001 Mar. 56 p. FRDC Project; Report No.:97/137.
29. de Lestang S, Hall NG, Potter IC. Reproductive biology of the blue swimmer crab (*Portunus pelagicus*, Decapoda: Portunidae) in five bodies of water on the west coast of Australia. FB. 2003; 101(4):745–57.
30. Marochi MZ, Moreto TF, Lacerda MB, Trevisan A, Masunari S. Sexual maturity and reproductive period of the swimming blue crab *Callinectes danae* Smith, 1869 (Brachyura: Portunidae) from Guaratuba Bay, Paraná State, Southern Brazil. Nauplius. 2013; 21(1):43–52.
31. Oh CW, Hartnoll RG. Size at sexual maturity, reproductive output, and seasonal reproduction of *Philocheras trispinosus* (Decapoda) in Port Erin Bay, Isle of Man. Journal of Crustacean Biology. 1999; 19(2):252–59.
32. Choy SC. Reproductive biology of *Liocarcinus puber* and L. *holsatus* (Decapoda, Brachyura, Portunidae) from the Gower Peninsula, South Wales. Marine Ecology. 1988; 9(3):227–41. doi:10.1111/j.1439-0485.1988.tb00330.x
33. Hines AH. Allometric constraints and variables of reproductive effort in brachyuran crabs. Marine Biology. 1982; 69(3):309–20.
34. Hines AH. Geographic variation in size at maturity in brachyuran crabs. Bull Mar Sci. 1989; 45(2):356–68.
35. Sumpton WD, Potter MA, Smith GS. Reproduction and growth of the commercial sand crab, *Portunus pelagicus* (L.) in Moreton Bay, Queensland. Asian Fish Sci. 1994; 7(2&3): 103–13.
36. Pinheiro MAA, Fransozo A. Reproduction of the speckled swimming crab *Arenaeus cribrariu*s (Brachyura: Portunidae) on the Brazilian Coast near 23°30'S. Journal of Crustacean Biology. 2002; 22(2):416–28.
37. Wardiatno Y, Zairion. Study on bio-ecology of the blue swimming crab and bio-economic performance of crab fishery in order to propose of spawning ground protection. Research project report. Bogor (ID): The Indonesia Blue-swimming Crab Management Association (APRI) in cooperation with Department of ARM-FFMS-IPB; 2011.
38. Potter IC, de Lestang S. Biology of the blue swimmer crab (*Portunus pelagicus*) in Leschenault Estuary and Koombana Bay, South Western Australia. J Roy Soc West Aust. 2000; 83(4):443–58.
39. Smith KD, Hall NG, de Lestang S, Potter IC. Potential bias in estimates of the size of maturity of crabs derived from trap samples. ICES Journal of Marine Science. 2004; 61: 906–12. doi:10.1016/ j.icesjms.2004.07.019.
40. Soundarapandian P, Varadharajan D, Boopathi A. Reproductive biology of the commercially important portunid crab, *Portunus sanguinolentus* (Herbst). J Mar Sci Res Dev. 2013. 3(2):1–9. doi:10.4172/2155-9910.1000124.
41. Soundarapandian P, Ilavarasan N, Varadharajan D. Reproductive system of flower crab, *Charybdis feriata* (Linnaeus). Open Access Scientific Reports. 2013; 2(4):1–7. doi:10.4172/scientificreports.701.
42. King M. Fisheries biology, assessment, and management. Oxford (GB): Fishing News. Books/Blackwell Scientific Books; 1995.
43. Fowler J, Cohen L. Practical statistics for field biology. New York (US): John Wiley & Sons Ltd.; 1992.
44. Campbell GR, Fielder DR. Size at sexual maturity and occurrence of ovigerous females in three species of commercially exploited portunid crabs in SE, Queensland. Proceedings of the Royal Society of Queensland 97; 1986; p. 79–87.
45. Johnson DD, Gray CA, William G, Macbeth WG. Reproductive biology of *Portunus pelagicus* in a South-East Australian Estuary. Journal of Crustacean Biology. 2010; 30(2):200–05. doi:10.1651/08-3076.1.
46. Hermanto DT. Study on growth and some reproductive biology aspect of the blue swimming crab (*Portunus*

pelagicus) in Mayangan waters, Subang, West Java [bachelor thesis in Indonesian language]. Bogor, (ID): Bogor Agricultural University (IPB); 2004.
47. Sunarto. Bio-ecological characteristic of the blue swimming crab (*Portunus pelagicus*) in Brebes marine waters, Central Java [dissertation in Indonesian language]. Bogor, (ID): Bogor Agricultural University (IPB); 2012.
48. Shield JD, Wood FEI. Impact of parasites on the reproduction and fecundity of the blue sand crab *Portunus pelagicus* from Moreton Bay, Australia. Marine Ecology Progress Series. 1993; 92:159–70.
49. de Lestang S, Hall NG, Potter IC. Changes in density, age composition, and growth rate of *Portunus pelagicus* in a large embayment in which fishing pressures and environmental conditions have been altered. Journal of Crustacean Biology. 2003; 23(4): 908–19. doi:10.1651/C-2376.
50. Dixon CD, Hooper GE. Blue crab (*Portunus pelagicus*) 2009/2010, Stock assessment report to PIRSA Fisheries. South Australian Research and Development Institute (Aquatic science); 2011. Adelaide (AU): SARDI Publication; SARDI Report Series. (531). Report No.:F2007/000729-7
51. de Lestang S, Hall NG, Potter IC. Influence of a deep artificial entrance channel on the biological characteristics of the blue swimmer crab *Portunus pelagicus* in a large microtidal estuary. J Exp Mar Biol Ecol. 2003; 295:41–61. doi:10.1016/S0022-0981(03)00273-9.
52. Chang Y, Sun C, Chen Y, Yeh S, Chiang W. Reproductive biology of the spiny lobster, *Panulirus penicillatus*, in the southeastern coastal waters of Taiwan. Marine Biology. 2007; 151(2):553–64. doi:10.1007/s00227-006-0488-9.
53. Fisher MR. Effect of temperature and salinity on size at maturity of female blue crabs. Transactions of the American Fisheries Society. 1999; 128(3):499–506. doi: 10.1577/1548-8659(1999)128.0499.
54. Dineshbabu AP, Sreedhara B, Muniyappa Y. Biology and exploitation of the blue swimmer crab, *Portunus pelagicus* (Linnaeus, 1758), from south Karnataka coast, India. Indian J Fish. 2008; 55(3):215–20.
55. Safaie M, Pazooki J, Kiabi B, Shokri MR. Reproductive biology of blue swimming crab, *Portunus segnis* (Forskal, 1775) in coastal waters of Persian Gulf and Oman Sea, Iran. IRAN J FISH SCI. 2013; 12(2):430–44.
56. Costa TM, Negreiros-Fransozo ML. The reproductive cycle of *Callinectes denae* Smith, 1969 (Decapoda: Portunidae) in Ubatuba Region, Brazil. Crustaceana. 1998; 71(6): 615–27.
57. Santos S, Negreiros-Fransozo ML. Reproductive cycle of the swimming crab *Portunus spinimanus* Latreille (Crustacea, Oecapoda, Brachyura) from Ubatuba, Sao Paulo, Brazil: Revista Brasileira de Zoologia. 1999; 16(4):1183–93.
58. Brown CE. Ovarian morphology, oogenesis, and changes through the annual reproductive cycle of the female blue crab, *Callinectis sapidus* Rathbun, in Tampa Bay [master thesis]. Tampa, Florida (US): College of Marine Science, University of South Florida (USF); 2009.
59. Kumar MS, Xiao Y, Venema S, Hooper G. Reproductive cycle of the blue swimmer crab, *Portunus pelagicus* off Southern Australia. JMBA. 2003; 83(5):983–94.
60. Svane I, Bryars S. Blue crab biology and key biological determinants important to the fishery, Chapter II. In: Svane I. and Cheshire A. editors. Fisheries biology and spatial modelling of the blue swimmer crab (*Portunus pelagicus*). SARDI Aquatic Sciences Publication; SARDI Research Report Series. (117): 2005. RD98/0200-2. p. 26–59.
61. Food and Agricultural Organization of the United Nations (FAO); Stock assessment for fishery management: A framework guide to the stock assessment tools of the Fisheries Management Science Programme (FMSP). Rome (IT): FAO Fisheries Technical Paper. 2006; (487).
62. Myers RA, Mertz G. The limit of exploitation: a precautionary approach. Ecol Appl. 1998; 8(1, supplement):s165–9.
63. Caddy JF, Mahon R. Reference point for fisheries management. Rome (IT): FAO Fisheries Technical Paper. 1995; (347).
64. Corgos A, Freire J. Morphometric and gonad maturity in the spider crab *Maja brachydactyla*: a comparison of methods for estimating size at maturity in species with determinate growth. ICES J Marine Sci. 2006; 63:851–9. doi:10.1016/j.icesjms.2006.03.003.