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Reproductive biology of blue swimming crab, *Portunus segnis* (Forskal, 1775) in coastal waters of Persian Gulf and Oman Sea, Iran

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Abstract

A reproductive biology study of blue swimming crab, *Portunus segnis* (Forskal, 1775) in the northern Persian Gulf and Oman Sea, was conducted from May 2010 to October 2011. The results showed that the annual sex ratio is not M: F=1:1, with 51.9 % female. All the five stages of ovarian development of *P. segnis* were observed throughout the year. The size of ovigerous crabs varied from 103 to 155 mm. carapace width. This crab can spawn all year round with a spawning peak in mid-winter to early of spring season. The fecundity of ovigerous crabs ranged from 521027 to 6656599 eggs, with average fecundity of 2397967 eggs. The minimum carapace width (CW) of female crabs that reach sexual maturity was 92-138 mm and the length at which 50% of all ovigerous females was 113 mm carapace width.

Keywords: Sex ratio, Sexual maturity at size, Spawning season, Fecundity, *Portunus segnis*, Persian Gulf, Oman Sea

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Introduction

Decapods crustacean form a major component of commercial fisheries in the Indo-Pacific region. The crab fishery is dominated by a few members of a single family, the Portunidae. They include four species of mud crab (genus *Scylla* De Haan, 1833), the blue swimming crab [*Portunus pelagicus* (Linnaeus, 1758)] and the gazami crab [*P. trituberculatus* (Miers, 1876)] (Lai et al., 2010).

Blue swimming crab is one of the economically important species that inhabit a wide range of inshore and continental shelf areas, including sandy, muddy and sea grass habitats, from the intertidal zone to at least 50 m depth. The blue swimming crab is found in near-shore and estuarine waters throughout the Indo-Pacific. Because of its good flavor, blue swimming crab is in high demand in the market (Sudtongkong, 2006).

Different groups of decapods crustacean exist in the Persian Gulf and Oman Sea which are caught during shrimp fishery season. Portunid crabs, especially *Portonus segnis*, are the most commercially important of all true crabs in coastal waters of Hormozgan province. In earlier studies, the blue swimming crab in the northern Persian Gulf was incorrectly identified as *Portunus pelagicus* (Kamrani *et al.*, 2010). Further investigations by Lai et al. (2010) showed that *Portunus segnis* is confined to the western Indian Ocean from Pakistan to South Africa. The results of present study mirrored the result by Lai et al. (2010) indicating that the blue swimming crab in the study area in the northern Persian Gulf is *P. segnis*.

Distributions of this species also extend from West Indian Ocean; West of Indian sub-continent, Pakistan, Persian Gulf, Red Sea, Mediterranean Sea, East coast of Africa(Lai et al., 2010).

The study of reproductive biology for specially spawning season and fecundity is important to have a full understanding of the population dynamics. Basic information related to population dynamics and biology of *P. segnis* is vital for policy makers and managers to establish regulation measures to conserve the population. Therefore, a study of reproductive biology of *P. segnis* can benefit the management of blue crab population in this area as well as in others.

In this paper sex ratio of males and females, gonad development, spawning season, size of females at sexual maturity and size at 50% maturity of ovigerous female and fecundity are presented for *P. segnis.*

Materials and methods

The study area extends from 26° 25′ E to 27° 07′ E and 57°29′ N to 56°06′ N, and samples were collected using shrimp bottom trawl with 20mm mesh size in cod end, which was stratified into three strata of 2–5, 5–10, and 10–20 m (Fig. 1). Samples were collected monthly from May 2010 to October 2011.

A total of 3746 male and 4056 female samples of this species were collected and preserved in a deep freezer until further analysis. Each crab was measured and recorded for its carapace width, body weight and sex determination. The carapace width (CW) was measured to the nearest mm across the tips of the epibranchial spines, and individual wet weights of the crabs were recorded to the nearest g. The number and carapace width (CW) of ovigerous females (Figure 2) were also examined and recorded.

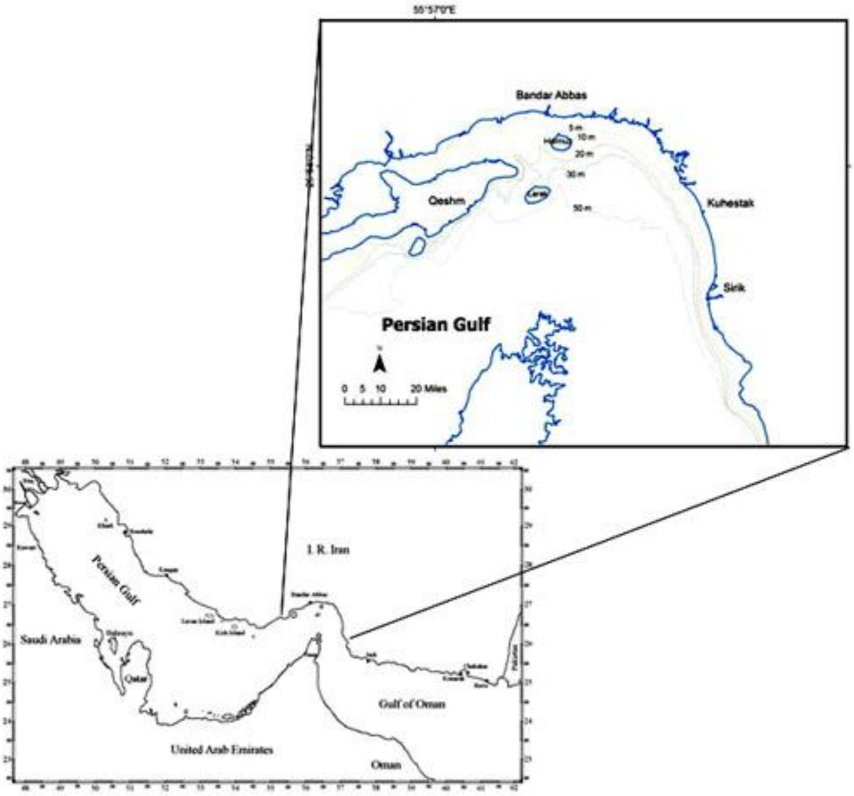

Figure 1: Locations of sampling sites for *Portunus segnis* in the Persian Gulf and Oman Sea

The determination of reproductive biology of blue swimming crab in Persian Gulf and Oman Sea was divided into 4 major parts described as follows.

Sex-Ratio

In this research, sex ratio analysis was carried out by monthly data sets of the total number of male and female crabs. Chi-square (X^2) statistical was performed to test the difference between ratios in both sexes.

Gonad Development and Spawning Season

1296 sampled females were measured for its biometric data. After opening its carapace for observation of the maturity stages of the ovaries, the maturity stages of ovaries were grouped into five main classes following the procedure adopted by Kumar et al. (2000).

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Figure 2: Ovigerous *P. segnis* collected from Persian Gulf and Oman Sea

Ovarian development was classified by size and color of the ovary as follows:

Stage 1- Gonad immature, ovary very thin and transparent (colorless).

Stage 2- Early gonad maturing, ovary changed color to creamy, but not extending into hepatic region.

Stage 3- Gonad maturing, ovary became enlarge and changed color to yellow, extending some 1/3-1/4 of the hepatic region.

Stage 4- Gonad mature, the ovary covered most part of hepatic region, and turned orange or reddish orange.

Stage 5- Females carrying eggs (Ovigerous female).

Spawning season of this species was found from the percentage of ovary stage 4 and ovigerous females in each month.

Size at First Sexual Maturity and Lm_{50}%

Examination of size at first sexual maturity of the female *P. segnis* were conducted using the minimum size class data of 603 ovigerous female crabs sampled from Persian Gulf and Oman Sea.

The mean length at first reproduction or mean length at sexual maturity (Lm) may be defined as the length at which 50% of all individuals are sexually matured. e.g. as the length at which 50% of all females in stock of crabs are ovigerous, or the length at which 50% of all female crabs have ovaries in an advanced stage of development. The Lm_{50}% was estimated by using following formula (King, 1995) and least square method (Solver Tools in Microsoft Excel ver. 2007):

$$P = L/[1+\exp(- r_m(L- L_{\mathbf{m50}}))]$$

Were, r_m is the slope of curve, L_m is the mean carapace width (mm) at sexual maturity, L is mean carapace width (mm) and P is probability of presence mature crabs.

Fecundity

Fecundity is calculated as the number of eggs carried externally by the female (Kumar et al., 2000).

In this study, 62 ovigerous females covering a wide size range were sampled by bottom trawl.

Carapace width of each ovigerous female was measured and the eggs of each ovigerous female were weighed to the nearest 0.001 g. At least 5 % of total egg weight was sub-sampled and counted under a stereo microscope. These data were then used to estimate the total number of eggs of each female. The relationship between fecundity (F) and carapace width (CW) was analyzed by using the equation:

$Fj= a+ b\,CWj$

Were, b is the slope of curve, a is constant number, CW is carapace width (mm) and F is fecundity.

Results

Sex ratio

The overall sex-ratio between male and female *P. segnis* caught from Persian Gulf and Oman Sea throughout the year is not 1:1, with a ratio of 51.9% females. Also, a Chi-square (X^2) test indicated that the overall sex-ratio was significantly different from the expected 1:1 ratio ($P< 0.05$) (Table 1, Figure 3).

Table 1: Sex–ratio between male and female of *P. segnis* collected from Persian Gulf and Oman Sea

Year	Date	Total(Obs.)			Sex Ratio		X^2 (p_{value})
		Male	Female	Total	Male	Female	
2010	May	41	22	63	1	0.54	0.02
	June	69	63	132	1	0.91	0.60
	July	82	102	184	1	1.24	0.14
	Aug	90	87	177	1	0.97	0.82
	Sept	178	116	294	1	0.65	0.00
	Oct	62	85	147	1	1.37	0.06
	Nov	13	24	37	1	1.85	0.07
	Dec	137	107	244	1	0.78	0.05
2011	Jan	64	90	154	1	1.41	0.04
	Feb	53	90	143	1	1.70	0.00
	Mar	27	56	83	1	2.07	0.00
	Apr	302	318	620	1	1.05	0.52
	May	109	131	240	1	1.20	0.16
	June	237	487	724	1	2.05	0.00
	July	654	703	1357	1	1.07	0.18
	Aug	596	645	1241	1	1.08	0.16
	Sept	1002	883	1885	1	0.88	0.01
	Oct	30	47	77	1	1.57	0.05
Total		3746	4056	7802	1	1.08	0.00

Gonad Development and Ovigerous Female

All the five stages of ovarian development of *P. segnis* were observed throughout the year in this Study (Fig. 4). The number of ovaries in stage 1 of development was higher during July (53.9 -64.2%) and August (55.2 – 69.8 %). January to April had very low percentages in that stage. Maturity stage 2 occurred in high percentages except July, August and September in 2011 (2.9, 2.6 and 3.7 %, respectively). While, maturity stage 3 occurred in low percentages except in June 2010 (29.0 %). The highest percentage of crabs in maturity stage 4 was observed from February to June in 2011. Ovigerous females (stage 5) were present in the samples throughout the year.

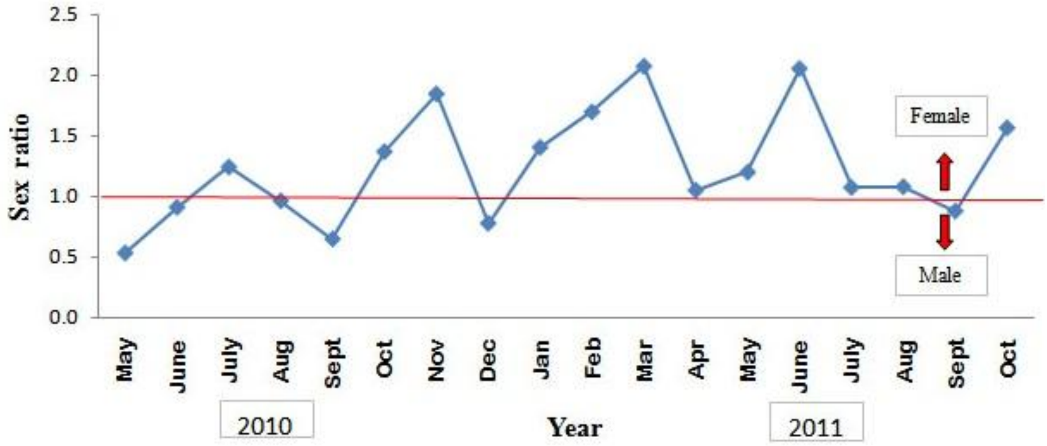

Figure 3: Sex–ratio between male and female of *P.segnis* from Persian Gulf and Oman Sea

The ovigerous females were present in the samples throughout the year, but the highest proportion of ovigerous females caught were in October and September in 2010 and 2011 respectively, with 55.3 % (for 2010) and 45.1 % (for 2011) of female catches. By contrast, the proportion of ovigerous was lowest in August for both year, with 21.8 % (for 2010) and 7.1 % (for 2011) of female catches.

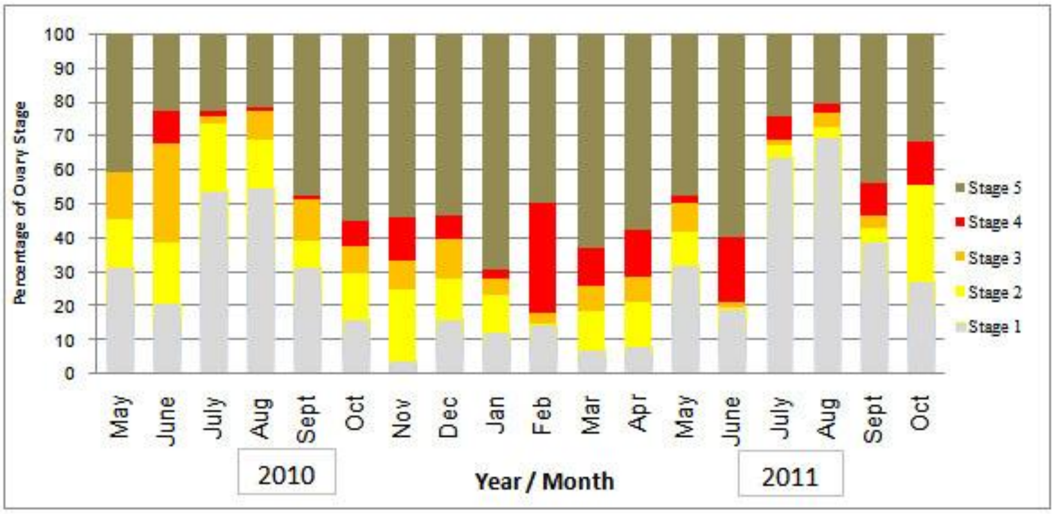

Figure 4: All maturity stages of female *P. segnis* sampled from Persian Gulf and Oman Sea

The percentage by month of gonad development and ovigerous female *P. segnis* were plotted (Figure 5) that indicating mature females were actively breeding throughout the 2010 to 2011. Concerning, the percentages of crabs in maturity stage 4 and 5 from January to April (from mid-winter to early of spring) were highest.

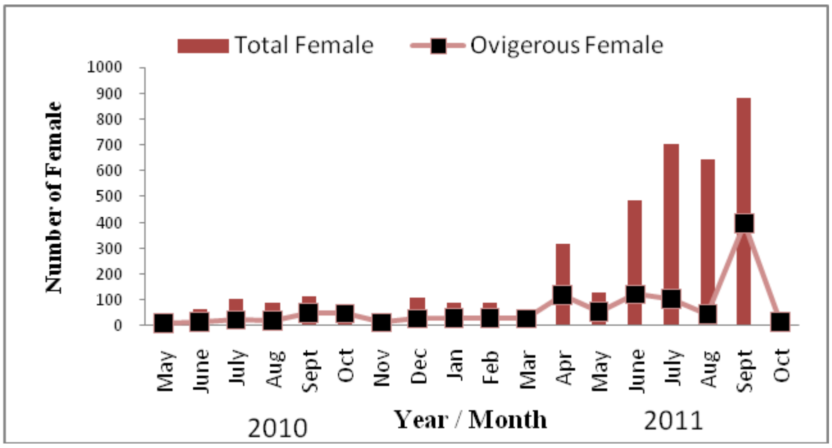

Figure 5: The relative abundance of ovigerous crabs sampled monthly from Persian Gulf and Oman Sea

Size at First Sexual Maturity and LM$_{50}$%

Size at first sexual maturity of female *P. segnis was* defined using the minimum size class data of ovigerous females. In this study, the carapace width of mature females ranged from 92-165 mm, with average size of mature females at 123.6± 15.7 mm carapace width (Table 2.). Figure 6 shows a logistic curve fitted the estimation of length at which 50 percent of female crabs are in stages 4 and 5,in which mean C.W. at sexual maturity is 113 mm.

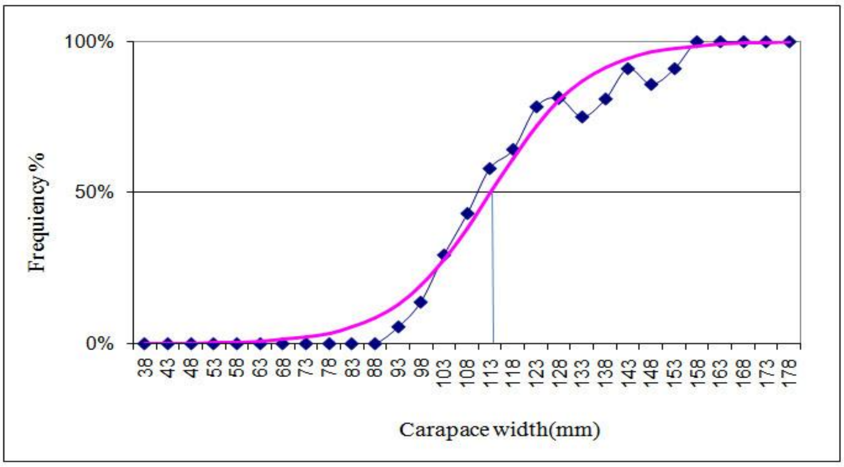

Figure 6: A logistic curve for estimation L$_m$50% of *P. segnis* from Persian Gulf and Oman Sea

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Table 2: Carapace width range of ovigerous female

Year	Month	Carapace width range (mm) of ovigerous female
2010	May	120 – 160
	June	93 -160
	July	92 -142
	Aug	110 -140
	Sept	100 -156
	Oct	107 – 145
	Nov	122 – 131
	Dec	117 -157
2011	Jan	138 – 151
	Feb	130 -159
	Mar	122 – 165
	Apr	95 – 163
	May	97 -135
	June	94 – 141
	July	105 – 153
	Aug	100 – 138
	Sept	105 – 152
	Oct	103 – 132

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Fecundity

Determination of fecundity of the female *P. segnis* from Persian Gulf and Oman Sea showed that each female with carapace width ranging between 103 to 155 mm can produce 521027 to 6656599 eggs. Mean fecundity of *P. segnis* in this study was 2397 967±1326721 eggs (Table 3, Fig. 7).

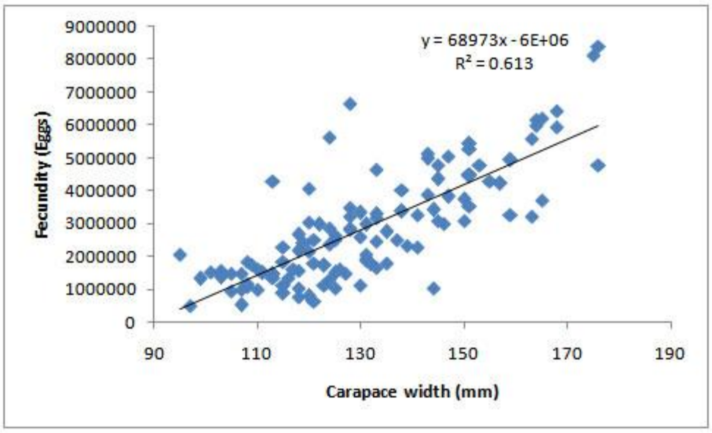

Figure 7: Relationship between carapace width and fecundity of *P. segnis*

Table 3: Fecundity in female *P. segnis* from Persian Gulf and Oman Sea

Ovigerous female	Number	Egg color	Range	Average ± S.D.
Carapace width(mm)			103 -155	123.7 ± 13.7
Egg number	28	Yellow	868242 - 5429437	2116518 ± 117631
Egg Diameter(wet)			26 -32	30 ± 2
Egg Diameter(dry)			18 – 22	19 ± 1
Carapace width(mm)			103 -147	126.9 ± 13.6
Egg number	16	Yellow – grey	1016935 - 4652311	2410908 ± 994431
Egg Diameter(wet)			26 -32	30 ± 2
Egg Diameter(dry)			14 – 22	18 ± 2
Carapace width(mm)			107 -150	126.8 ± 12.4
Egg number	18	Grey	521027 - 6656598	2752298 ± 167641
Egg Diameter(wet)			26 -33	31 ± 2
Egg Diameter(dry)			15 – 21	19 ± 1

Discussion

The difference from the expected 1:1 ratio between male and female of *P. segnis* may result from its behavior and migration. Mature *P. pelagicus* display differences in habitat preferences for male and female crabs (Weng, 1992). Generally, females leave inshore estuarine areas and move offshore to spawn. Meagher mentioned this migration is thought to be necessary for the survival of the larvae due to lowered oxygen levels and lack of suitable

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food in estuaries (Sudtongkong, 2006). Potter et al. (1983) revealed that female *P. pelagicus* are more abundant in shallow areas, particularly on the tops of sandbanks.

Females are known to require sandy substrate for successful egg extrusion and attachment to the pleopods (Kangas, 2000). It is likely that migration of mature females onto sandbanks for egg extrusion was at least partially responsible for the variation of sex ratio which was most noticeable immediately prior to the spawning season (Sumpton et al., 1994). Also changes in feeding behavior can also reduce the attractiveness of commercial pots to female crabs during the spawning period (Xiao and Kumar, 2004).

The unequal sex ratio can be attributed to the effects of fishing gear. The Hormozgan fishers use a variety of gears, shrimp bottom trawl, bottom set gillnet, fish traps and stake-nets for crab fishing. Gillnet usually operates in the deeper area, while trawl performs in the shallow waters. Differences in types and methods of fishing gear may influence the sex ratio in the catch. Many articles presented the effect of fishing gear on the dissimilar sex-ratio of this species. Kangas (2000) proposed that the effect of fishing gear resulted in the differential in sex ratio. For instance, the set nets method could capture more males than females of *P. pelagicus* in the Bunbury region. Crabs catches by crab pots in the Leschenaultia Estuary showed a higher proportion of males, with a sex ratio of 3.8: 1.0, while those in Koombana Bay were in the ratio 1.7:1.0 (Kangas, 2000). This result is similar to the sex ratio in *P. pelagicus* Xiao and Kumar (2004) from South Australia; likewise, other papers did not specify the sex ratio in *P. pelagicus* in different countries: Sudtongkong (2006) from southern Thailand; Dineshbabu et al. (2008) from South Karanataka coast, India.

All the five stages of ovarian development of *P. segnis* were observed throughout the 2010 and 2011 years (Fig. 4). This result is similar to the finding of Kumar et al. (2000) in South Australia waters and Sudtongkong (2006) in Southern Thailand who observed *P. pelagicus* to have all stages of ovarian development all year round. In tropical regions, *P. pelagicus* breeds throughout the year (Batoy et al., 1987), whereas reproduction is restricted to the warmer months in temperate regions (Smith, 1982). Svane and Hooper (2004) reported that the fourth stage of ovarian development of *P. pelagicus* was observed in late October to November in conjunction with rising sea water temperature.

The ovigerous females *P. segnis* were present in the samples throughout the year. Also maturity stages 4 and 5 occurred throughout the year. This finding is similar to research conducted in Australia (Penn, 1977; Smith, 1982) and Sudtongkong (2006) in Southern Thailand. De Lestang et al. (2003) stated that the development of ovarian and egg in *P. pelagicus* are controlled by water temperature. In South Australian waters,

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berried females of *P. pelagicus* very rarely appear in the commercial catch between April and September, when the temperature is relatively low. The peak period for ovary maturation and spawning starts in October, with peak proportions of berried females occurring in November – December (Clarke and Ryan, 2004). High proportion of ovigerous females in Sikao Bay in Thailand during the early of dry season, December, indicated the influential of water temperature on ovulation and egg development of *P. pelagicus* (Sudtongkong, 2006).

The percentage by month of gonad development and relative abundance of ovigerous female *P. segnis* were plotted (Figures 4, 5) and showed these crabs were actively breeding throughout the year. Concerning, there were spawning peaks from January to April (from mid-winter to early of spring), when the percentages of crabs in maturity stages 4 and 5 were the highest.

Development of the ovaries in females of *P. pelagicus* in Australia appears to be triggered by rising water temperatures in spring (Svane and Hooper, 2004). Spawning takes place all year in tropical and subtropical waters. Reproduction in temperate regions is restricted to the warmer months (Kangas, 2000). The occurrence all year round of ovigerous female *P. pelagicus* is the same as the spawning cycle of crab population in Australia (Kumar et al., 1999) and Thailand (Sudtongkong, 2006). The spawning season of *P. pelagicus* in India activity occurred during February-March (Dineshbabu et al., 2008) and in South Australia lasts for 3 to 4 months over the summer/autumn period (Svane and Hooper, 2004). In tropical regions where water temperature is traditionally higher, *P. pelagicus* generally experiences constant reproduction, with peaks occurring in those months with higher temperatures (Potter et al., 1998). Perhaps, increase the water temperature in mid-winter to early of spring season in south Iran is the primary environmental factor influencing reproduction. Also salinity is one of important parameter which can influence growth and reproduction of *P. pelagicus.* In tropical, the salinity of shallow coastal areas normally decreases in rainy season, due to the great amount of water runoff. Low salinity condition of the coastal habitat is unsuitable for *P. pelagicus*. In the Peel-Harvey Estuary, Australia, crabs were no longer caught in winter when rainfall reduces the salinity to less than 10**%** (Potter et al., 1983). Meagher noted that *P. pelagicus* prefers salinity levels between 30 and 40 ppt. (Sudtongkong, 2006). Moreover, the crab in larvae stage needs to grow and survive in stable and high salinity conditions.

In this study the minimum carapace width (CW) range of ovigerous female *P. segnis* that reach sexual maturity was 92-138 mm and the length at which 50% of all females in stock of crabs are ovigerous was 113 mm carapace width.

In South Australia male and female *P. pelagicus* generally reach sexual maturity at a size of 70 to 90 mm in carapace width, when they are

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approximately one year old (Svane and Hooper, 2004). The size at first maturity varies with latitude or location (Campbell and Fielder, 1986; Sukumaran and Neelakantan, 1996) and within individuals at any location. For example, the minimum carapace width (CW) of female crabs that reach sexual maturity ranged from 61 mm in both the Peel-Harvey Estuary and Shark Bay to 84 mm in the Leschenault Estuary (De Lestang et al., 2003). Clarke and Ryan (2004) stated that about 82 mm CW females in Australia can become sexually mature. In India, males may reach sexual maturity at a CW ranging 85 to 90 mm, and females at 80-90 mm CW (Sukumaran and Neelakantan, 1996). Moreover, the carapace width at which *P. pelagicus* reaches sexual maturity vary depending on growth rate, which is a direct function of temperature. For example, the carapace width at which 50% of both males and females reach sexual maturity in Cockburn Sound, Western Australia is 97mm, in India size at maturity (50%) of female was estimated at 96 mm carapace width (Dineshbabu et al., 2008), while in the Philippines, 50% of females reach sexual maturity at 106 mm carapace width (Sukumaran and Neelakantan, 1997).

Fecundity determination of the female *P. segnis* from Persian Gulf and Oman Sea showed that each female with carapace width ranging between 103 to155 mm can produce 521027 to 6656599 eggs. Mean fecundity of *P. segnis* in this study was 2397967±1326721 eggs (Table 3, Figure 7).

Fecundity estimated in this study for *P. segnis* is more than of *P. pelagicus* in other countries. In Southern Thailand the fecundity of ovigerous crabs was ranged from 27040 to 1725179 eggs, with average of 474,550 eggs (Sudtongkong, 2006); in Indonesia the fecundity of *P. pelagicus* under cultured conditions was ranged from 148897 to 835401 eggs (Arshad et al., 2006); in South Australia Kumar et al. (2000) found that a female *P. pelagicus* can produce between 650000 to 1760000 eggs per spawning. Whereas, in the west coast of Australia, De Lestang et al.(2003) was found that fecundity of *P. pelagicus* during the spawning season ranged from about 78000 in small crabs (CW=80 mm) to about 1000000 in large crabs (CW=180 mm).

Generally, female *P. pelagicus* may spawn up to two million eggs per batch, but the number of eggs produced by females varies with the size of the individual as well as between individuals of a similar size (Sudtongkong, 2006).

Kumar et al. (2003) found that the fecundity of female crabs is size-dependent. Fecundity increased by 83.9% with an increase of carapace width from 105 to 125 mm, implying that a single large female could produce as many eggs as two small females.

The analysis of carapace width and fecundity relationship for *P.segnis* in the Persian Gulf and Oman Sea to be F=0.063828(CW) + 0.06 that indicated the fecundity increases with an increase of carapace width (R^2=0.37), as shown in Figure 7. High fecundity was found in larger crabs due to a longer inter molt period between population and egg extrusion than small crabs, i.e. eight versus four months. So they have more time to accumulate the energy reserves required to produce eggs. This difference accounts for the greater number of eggs produced by larger than small crabs (De Lestang et al., 2003).

Fecundity of crabs varies from species to species and also varies within the same species due to different factors such as age, size, nourishment, ecological conditions of the water body etc. Variation in fecundity was primarily a reflection of variation in the size of the crab at maturity (Arshad et al., 2006). Additionally, estimates of the fecundity of crabs have typically been based on the number of eggs in a single batch of eggs. However, such an approach does not take into account the fact that female crabs often produce more than one batch of eggs during a spawning season (De Lestang et al., 2003).

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