Reproductive Biology of the Blue Swimming Crab, *Portunus pelagicus* (Linnaeus, 1758) in the Coastal Waters of Trang Province, Southern Thailand

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ABSTRACT

The blue swimming crab (*Portunus pelagicus*) is an important commercial species in Trang province, Southern Thailand. This study investigated the reproductive biology that supports the largest regional small-scale fishery of this species. A total of 217 male and 214 female crabs were randomly sampled from the catches of small-scale fishers, on a monthly basis from October 2010 to September 2011. All stages of gonad (testes and ovaries) development of crabs were observed throughout the year. The monthly mean values of Gonadosomatic Index (GSI) of male and female crabs ranged between 1.34 to 3.25, and 2.60 to 9.24%, respectively. Spawning season occurred twice a year, from December to February, and July to September. The sizes at 50% maturity (ICW50%) of male and female crabs were 8.02 and 8.09 cm, respectively. The fecundity of ovigerous crabs ranged widely from 98,627 to 1,319,480 eggs, with the average of 472,357 eggs. The fecundity of good breeder females ranged from 133,669 to 606,026 eggs.

Keywords: *Portunus pelagicus*, reproductive biology, Trang Province, Thailand

INTRODUCTION

The blue swimming crab, P*ortunus pelagicus* (Linnaeus,1758), is an economically important marine species with high market demand. The species is distributed throughout the coastal waters of the tropical regions of the western Indian and eastern Pacific Oceans (Lee and Hsu, 2003; Xiao and Kumar, 2004; Johnson *et al*., 2010). It inhabits sandy, muddy and seagrass habitats, from the intertidal zone to at least 50 m depth (Williams, 1982; Edgar, 1990; Clarke and Ryan, 2004; Kamrani *et al*., 2010; Hosseini *et al*., 2012).

In Thailand, blue swimming crab is distributed in the Andaman Sea and the Gulf of Thailand. The blue swimming crab fishery is a major source of livelihood for small-scale fishers in many parts of the

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coastal area. Trang province is one of the six provinces bordering the Andaman Sea (Figure 1). Several marine species, including fin fish, shrimps and crabs are harvested by small-scale fishers in Trang coastal waters. Blue swimming crab fishery in Trang province is an important source of income for small-scale fishers (Sudtongkong, 2006; Songrak and Choopunth, 2006; Songrak *et al*., 2013).

The production of blue swimming crab in Thailand during 2005 was approximately 3,000 tons per year (Oniam *et al*., 2010; Arkronrat *et al*., 2013). However in 2008, exports fell rapidly due to low production. In addition, the size of blue swimming crabs was also smaller than in the previous years and the crab fisheries in Trang province decreased by approximately 40 percent (Songrak and Choopunth, 2006; Sawusdee and Songrak, 2009).

Knowledge of the reproductive biology of a species is one of the most important aspects in fishery management and harvesting strategies (Sawusdee and Songrak, 2009; Johnson *et al*., 2010). Studies investigating aspects of the reproductive biology of blue swimming crab have reported regional and area-specific differences in factors such as age, size, timing and range of spawning season, fecundity, and size at first maturity (Sukumaran and Neelakantan, 1997; De Lestang *et al*., 2003; Kumar *et al*., 2003; Smith *et al*., 2004; Xiao and Kumar, 2004; Arshad *et al*., 2006).

There have been no studies into the reproductive biology of blue swimming crab in Trang seacoast, or the Andaman Sea, even though they support substantial crab fisheries. The life history of blue swimming crab on the Trang seacoast may differ from populations elsewhere. Basic information of the reproductive biology of blue swimming crab is therefore required to help determine appropriate management options for this species in Trang province, southern Thailand (Sudtongkong, 2006; Songrak and Choopunth, 2006; Sawusdee and Songrak, 2009; Songrak *et al*., 2013). This study examined reproductive biology of males and females, including gonad development, spawning season, fecundity and size at first maturity of *P. pelagicus.*

MATERIALS AND METHODS

Study area

This study was conducted in Trang province, southern Thailand along 136 km of coastline between longitude 99º 10′ to 99º 35′ E and latitude 7º 5′ to 7º 27′ N (Figure 1). The area supports a large proportion of the landings, around 25% of blue swimming crabs in the Andaman Sea, and covers an area of 650 km^2 including the intertidal zone down to between 5 and 50 m in depth (Songrak *et al*., 2013).

Sample collection

Blue swimming crabs were sampled on a monthly basis during October 2010 to September 2011 from small-scale fishers who collected this species from districts along the Trang seacoast. They were taken from six fishing villages, namely (1) Ban Lhamsai, (2) Ban Chang Lang, (3) Ban Nam Rab, (4) Ban Pramung, (5) Ban Haad Sum Ran and (6) Ban Yong Star.

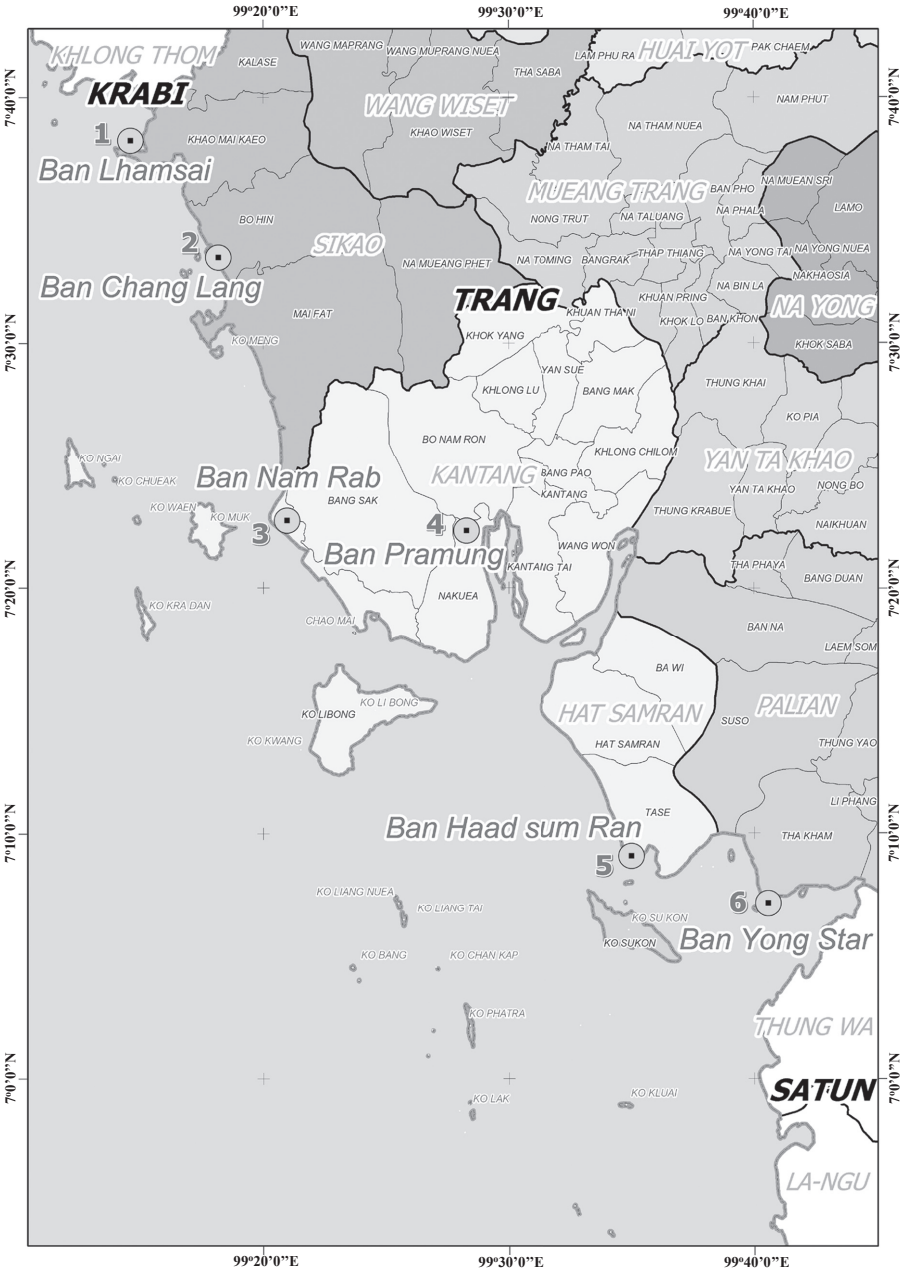

Figure 1. Map of Trang seacoast showing sampling stations and study sites

Each month a total of 36 crabs (18 males and 18 females) were randomly selected to study the size at 50% maturity of ovigerous, gonad development in blue swimming crabs and fecundity. All samples of blue swimming crabs were taken to the laboratory and stored in a deep freezer until further analysis. Inner carapace width (ICW, nearest cm) and body weight (BW, nearest g) of the sample crabs were also measured.

Reproductive biology

The determination of reproductive biology of blue swimming crab in Trang seacoast were divided into 3 major classifications, described below.

Gonad development and spawning season

After opening the carapace for observation of the maturity stages of testes and ovaries, the maturity stages of testes were grouped into two main classes following the procedure adopted by Soundarapandian *et al*. (2013). The maturity stages of ovaries were grouped into four main classes following the procedure adopted by Kumar *et al*. (2000) and De Lestang *et al*. (2003); Johnson *et al*. (2010).

Testes development was classified by size and color of the testis as follows:

Stage I: Immature: The testes of the immature crabs are small, and creamy in color, lying on either side of the stomach. Testes and vas deferentia are not clearly differentiated. Crabs with carapace length below 9.5 cm show immature testes.

Stage II: Maturing: Testes and vas deferentia are well developed, clearly differentiated and creamy white in color. Testes appear as a large coiled tube which spread laterally and posteriorly to the stomach. Anterior vas deferentia is enlarged whilst middle and posterior vas deferentia are straight and opaque, extending to both the sides of the heart.

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

Stage I: Immature: ovaries are very thin and transparent (colorless).

Stage II: Maturing: ovaries change color to creamy, but not extending into hepatic region.

Stage III: Maturing: ovaries become enlarged and change color to yellow, extending some 1/4 - 1/3 of the hepatic region.

Stage IV: Mature: ovaries cover most of the hepatic region, and turn orange or reddish orange in color.

The testes and ovaries were then removed and weighed. The Gonadosomatic Index (GSI) was calculated following Quinn and Kojis (1987); Kamrani *et al*. (2010):

GSI_{male} = (Testis weight / Total weight) * 100%

GSI_{female} = (Ovary weight / Total weight) * 100%

Spawning season of the blue swimming crabs was forecasted by calculating the percentage of stage IV ovaries and ovigerous females and GSI in each month. The highest values of these parameters occur on the month of maximum spawning (Litulo, 2005).

Size at first sexual maturity

The size at sexual maturity ($ICW_{50\%}$) of the female crabs was determined by examining 214 ovigerous female crabs. The

mean inner carapace width at sexual maturity (ICW_m) may be defined as the length at which 50% of all individuals are sexually mature. The size of actively breeding female crabs was estimated by $ICW_{25\%}$ and $ICW_{75\%}$. The size of crabs at sexual maturity was estimated using the following formula (King, 2007; Kamrani *et al*., 2010) and least square method (Solver Tools in Microsoft Excel) (Thapanand, 2006):

$$P_L = \frac{1}{1 + e^{(a+bICW)}}$$

Where; P_L = proportion of breeder crabs per total crabs
ICW = inner carapace width
a,b = constant values

ICW formula:

$$ICW_{25\%} = \frac{a - \ln 3}{b}$$

$$ICW_{50\%} = \frac{a}{b}$$

$$ICW_{25\%} = \frac{a + \ln 3}{b}$$

Fecundity

Fecundity was calculated as the number of eggs carried externally by the female crab (Kumar *et al*., 2000; Kamrani *et al*., 2010; Rasheed and Mustaquim, 2010). In this study, 214 ovigerous females, covering a wide size range, were collected from blue swimming crab fisheries along the Trang seacoast.

ICW of each female was measured and their eggs weighed to the nearest 0.001 g. At least 5% of total egg weight was sub-sampled and the number of eggs counted under a stereo microscope. This was then used to estimate the total number of eggs of each female (Omolara and Barakat, 2009).

RESULTS

Gonad development

Testes development of male blue swimming crabs in Trang seacoast was observed throughout the year (Figure 2). The number of immature testis in stage I was higher during November, May and June (50.00%). September and December had very low percentages in that stage (22.22%). The percentage of mature testis in stage II was high except in September and December (77.78%). However, mature stage II occurred throughout the year, indicating that male blue swimming crabs were actively breeding all year round.

The GSI of testes development was higher during August, June and October (3.25, 3.14 and 2.83%, respectively) (Table 1). Monthly mean values ranged from 1.34 to 3.25% (Figure 3).

All four stages of ovarian development of female blue swimming crabs were observed throughout the year in Trang seacoast (Figure 4). The percentage of ovaries in stage I of development was highest in October (28.57%), whereas from December

Table 1. Number of ovigerous crab samples from Trang seacoast from October 2010 to September 2011

Month	Number of blue swimming crab		Number of ovigerous crabs		% Ovigerous		% GSI	
	Male	Female	Male	Female	Male	Female	Male	Female
Oct	16	14	11	1	68.75	7.14	2.83	3.12
Nov	18	17	9	3	50.00	16.67	1.34	2.60
Dec	18	18	14	2	77.78	11.11	2.35	3.26
Jan	21	21	12	10	57.14	47.62	2.30	9.24
Feb	18	18	11	7	61.66	38.89	1.44	5.22
Mar	18	18	12	8	66.67	44.45	2.04	6.83
Apr	18	18	12	9	66.67	50.00	2.02	6.76
May	18	18	9	6	50.00	16.67	2.13	6.09
Jun	18	18	9	6	50.00	33.33	3.14	7.09
Jul	18	18	11	6	61.11	33.34	2.07	5.57
Aug	18	18	11	10	61.11	55.56	3.25	7.98
Sep	18	18	14	5	77.78	27.78	2.98	5.20

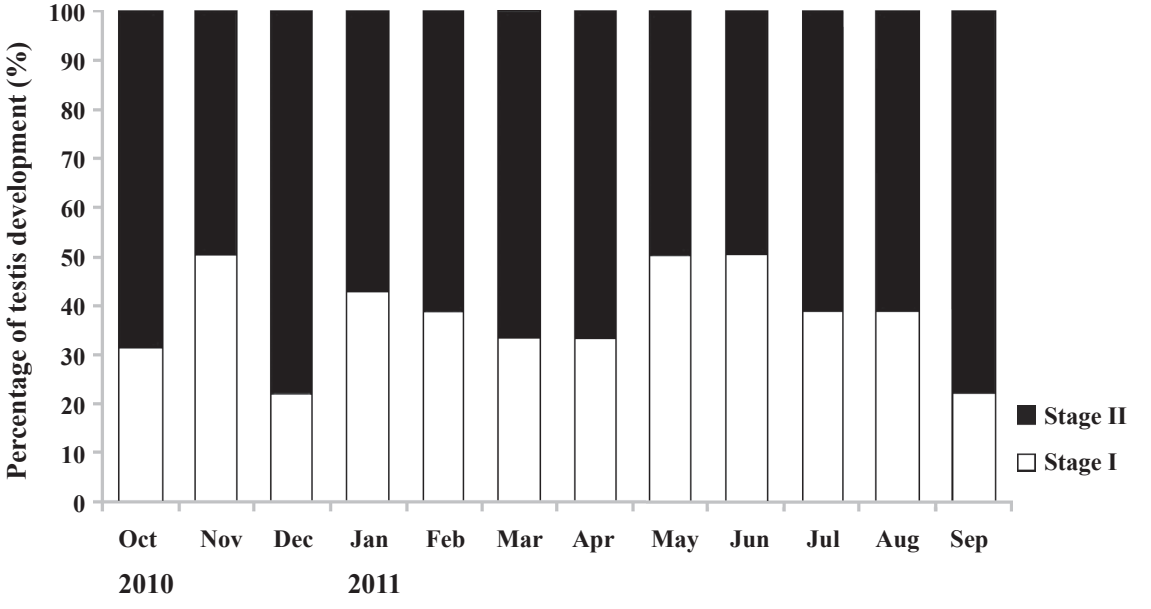

Figure 2. Testis development of male blue swimming crabs from Trang seacoast from October 2010 to September 2011].

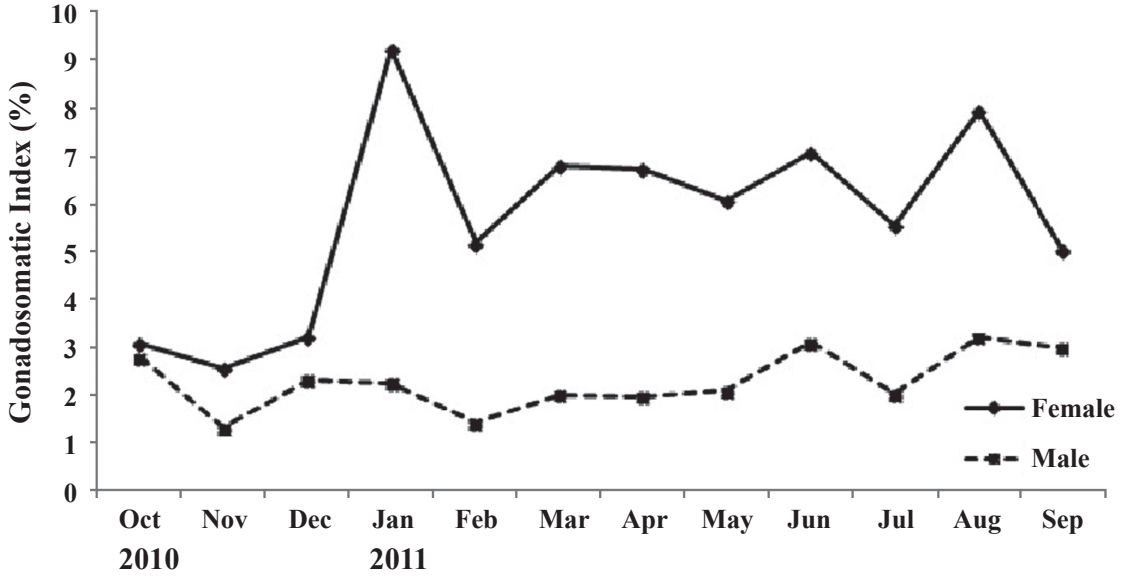

Figure 3. The GSI of male and female blue swimming crabs from Trang seacoast from October 2010 to September 2011

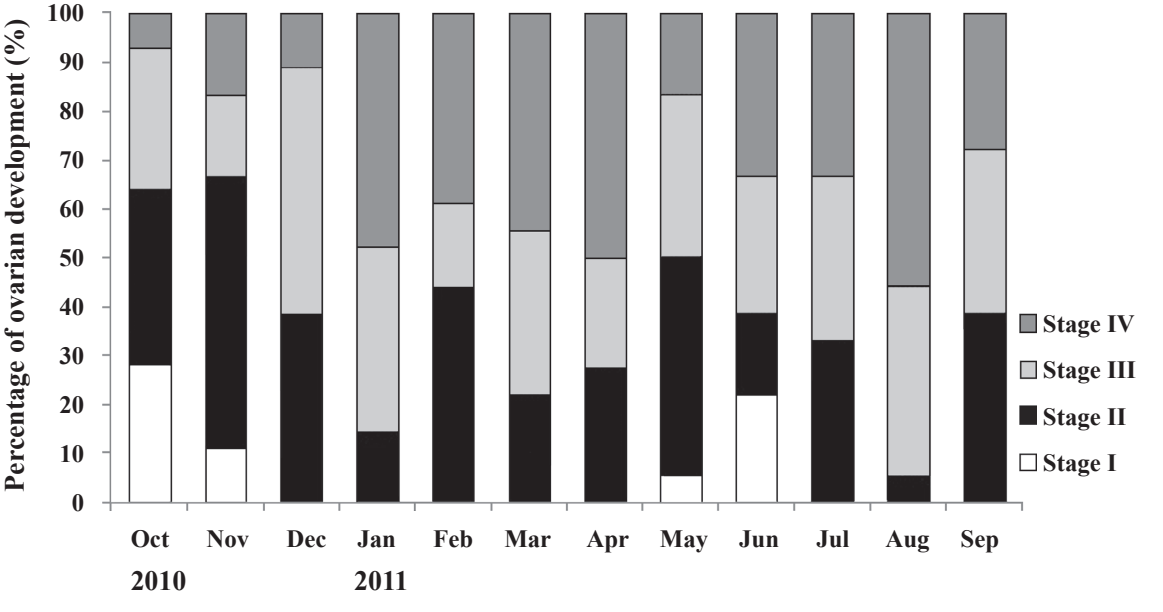

Figure 4. Ovarian development of female blue swimming crabs from Trang seacoast from October 2010 to September 2011

to April, the percentages at this stage were low. Percentage of maturity stage II was high in all months except in November, February and December (55.56, 44.44 and 38.89%, respectively). Maturity stage III occurrence was also high except in December, January and August (50.00, 38.10 and 38.89%, respectively). The highest percentage of blue swimming crabs in maturity stage IV was found from January to March (47.62, 38.89 and 44.45%, respectively). However, maturity Stage IV occurred throughout the year, indicating that mature females can also breed throughout the year.

The GSI of female crabs for January, August and June were 9.24, 7.98 and 7.09%, respectively (Figure 3) which showed high values all year. However, based on the percentages of stage IV of matured crabs, there were two periods of spawning season. Firstly, from December to February, and secondly, from July to September.

Size at first sexual maturity

Sizes at 50% maturity ($ICW_{50\%}$) of male and female *P. pelagicus* were determined using the proportion of mature crabs (P_{ICW}). The $ICW_{50\%}$ of mature males and females were 8.02 and 8.09 cm, respectively. In this study, the size of actively breeding female crab was derived from P_{ICW}=0.25-0.75; $ICW_{25\%}$ - $ICW_{75\%}$. The $ICW_{25\%}$ of mature males and females were 6.43 and 7.88 cm, respectively, and the $ICW_{75\%}$ of mature males and females were 9.58 and 8.30 cm, respectively.

The logistic functions for the estimation $ICW_{50\%}$ of blue swimming crab were $P_{ICW} = \frac{1}{1+e^{(5.57-0.69*ICW)}}$ in male, and $P_{ICW} = \frac{1}{1+e^{(5.57-0.69*ICW)}}$ in female (Figures 5 and 6).

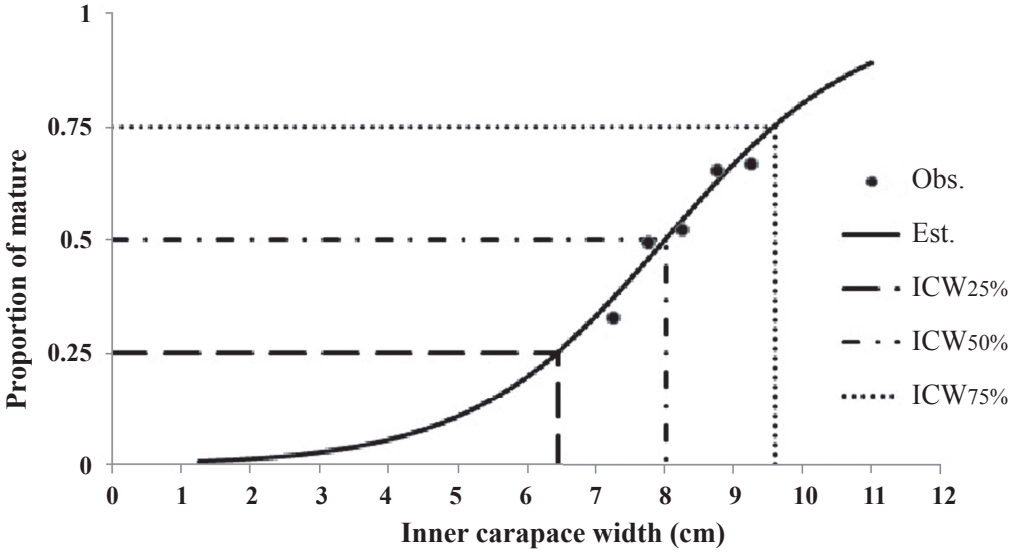

Figure 5. Size at 50% maturity of male blue swimming crabs from Trang seacoast

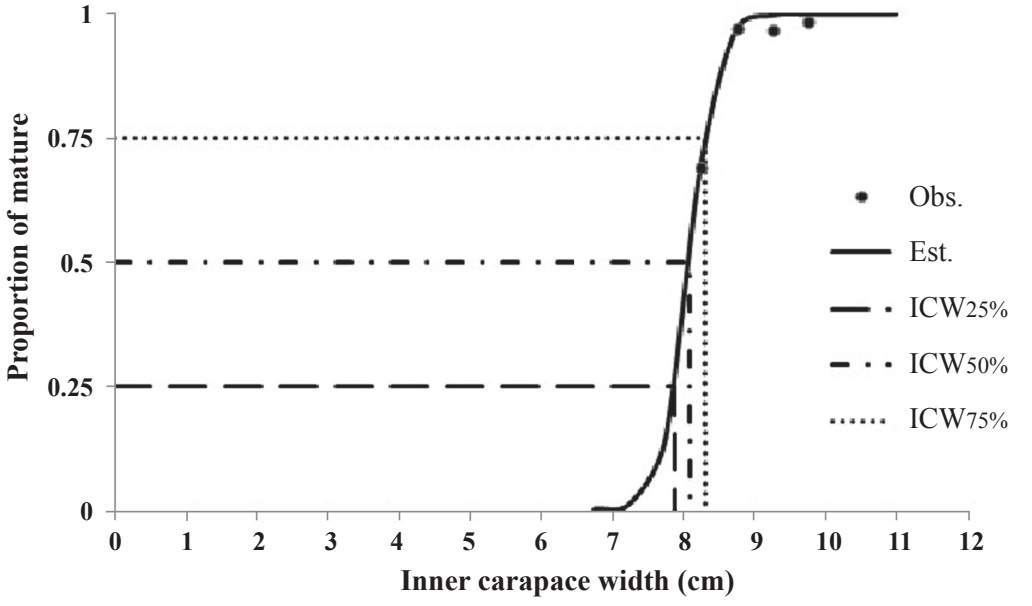

Figure 6. Size at 50% maturity of female blue swimming crabs from Trang seacoast

Fecundity

The results show that females with an inner carapace width between 7.68 and 11.22 cm had a wide range of fecundity, from 98,627 to 1,319,480 eggs. The mean fecundity in this study was 472,357±227,903 eggs. The range for good breeders was calculated by applying a size at first maturity of female crab. With the size of actively breeding female crab ($ICW_{25\%}$ - $ICW_{75\%}$) ranging from 7.88 - 8.30 cm, the fecundity could range from 133,669 to 606,026 eggs.

DISCUSSION

The reproductive biology of blue swimming crabs on the Trang seacoast was considerably different from that in the other parts of the tropical region, confirming that regional differences do exist in their reproductive biology (Table 2). However, the testis and ovarian development of crabs was similar to the findings of Kumar *et al.* (2000) in South Australia. Normally in tropical areas, blue swimming crabs breed throughout the year (Batoy *et al.*, 1987), whereas reproduction is restricted to the warmer months in the temperate zone (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 seawater temperature.

Ovigerous females were present throughout the year, but the highest proportion occurred in August (55.56%), April (50.00%) and January (47.62%). On the other hand, the proportion of ovigerous females was lowest in October with 7.14% of female

Table 2. Comparative findings of the reproductive biology of *P. palagicus* (ICW = Inner carapace width, OCW = Outer carapace width, CL = Carapace length)

Location	Size at maturity (cm) in		Fecundity (Eggs x 10^6)	Seasonal peaks	Source
	Male	Female			
Trang seacoast	8.02 (ICW)	8.09 (ICW)	0.13-0.60	Dec-Feb	Present study
India	-	-	0.25-0.75	Jan-Apr	Sukumaran and Neelakantan (1977)
Egypt	-	3.1-4.4 (CL)	0.75-0.81	Apr-Sep	Razek (1988)
Sikao bay	-	7.00 (OCW)	0.27-1.73	Jul-Dec	Sudtongkong (2009)
New South Wales Australia	-	3.8-5.6 (CL)	0.46-1.78	Nov-Dec	Johnson *et al*. (2010)
South Australia	-	2.8-4.9 (CL)	0.48-1.60	Oct-Apr	Smith (1982)
Northern Persian Gulf	-	3.20 (CL)	2.77-1.11	Dec-Jul	Kamrani *et al*. (2010)

catches having eggs (Table 1). This finding is similar to a research conducted in Australia, which found that most ovigerous crabs were caught during November to January (Penn, 1977; Smith, 1982). Larval sampling in the St Vincent Gulf, South Australia, indicated that the main hatching period of the blue swimming crab extends from November to March (Bryars, 1997). Gaughan and Potter (1994) found larvae of *P. pelagicus* in the lower Swan Estuary between September and April, with a peak in January and February. De Lestang *et al*., (2003) reported that the development of ovaries and eggs in *P. pelagicus* was controlled by water temperature. In South Australian waters, berried females (females carrying eggs externally) rarely appear in commercial catches between April and September, when the temperature is relatively low. The peak period for ovarian maturation and spawning starts in October, with peak proportions of berried females occurring in November-December (Clarke and Ryan, 2004).

For fecundity, this finding is similar to that of Smith (1982), who found that a female blue swimming crab could produce between 480,000 to 1,600,000 eggs (Table 2). Generally, blue swimming crabs may spawn up to 1.5 million eggs per batch. However, the number of eggs produced by females varies with the size of the individual as well as between individuals of a similar size (Bezerra and Cascon, 2007; Kamrani *et al*., 2010; Johnson *et al*., 2010).

The fecundity of blue swimming crabs is directly related to the size of the individual (Kumar *et al*., 1999; Sudtongkong, 2009). In New South Wales, Southeast Australia, the number of eggs recorded for a single batch of eggs ranged from 463,000 eggs in a crab with carapace length of 5.69 cm to 1,751,000 eggs in a crab with carapace length of 7.66 cm (Johnson *et al*., 2010). Arshad *et al*. (2006) found that the fecundity of female crabs is size-dependent, i.e. fecundity was 148,897 to 835,401 eggs per

batch in a crab with carapace width ranging from 10.22 to 14.05 cm. High fecundity was found in larger crabs because of a longer inter molt period, between growth and egg extrusion, than smaller crabs (Kamrani *et al*., 2010), as they have a longer period to accumulate the energy reserves required to produce eggs (De Lestang *et al*., 2003).

CONCLUSION

The examination of the reproductive biology of blue swimming crab, *P. pelagicus*, in Trang seacoast, Southern Thailand, provided useful information for the management of this species. The information has implications on policies and practices related to the prohibition on the capture of ovigerous female crabs, size limitation for female crabs fishing which should bigger than $ICW_{50\%}$; and regulation on prohibition of fishing during the spawning season in this area.

At present, the exploitation of blue swimming crab in Trang seacoast is nearly equal to its recruitment, so the sustainable utilization of blue swimming crab should be carried out under good management (Sawusdee and Songrak, 2009). The level of fishing effort should be maintained at the present level to protect against overfishing.

The management measure for blue swimming crab in Trang seacoast as suggested by stock assessment in fishery is to control the number of small-scale fishing gears, i.e. should not be more than the present levels (Sawusdee and Songrak, 2009). The decision-making on blue swimming crab management could not be based only on biological information but also on the socioeconomic conditions of small-scale fishers in Trang province. A holistic consideration of these factors is necessary in order to achieve sustainable management of blue swimming crab resources and also to ensure fairness for all stakeholders.

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