FISHERIES SCIENCE 2005; **71**: 20–28

Growth and reproduction of the red frog crab, *Ranina ranina* (Linnaeus, 1758), in the Andaman Sea off Thailand

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ABSTRACT: Studies were conducted on growth and reproduction of the red frog crab, *Ranina ranina* (Linnaeus, 1758), in the Andaman Sea off Thailand from 1998 to 1999. Samples were collected from Ko Similan, Ko Surin and Thai-Myanmar boundary waters by gill net. Results showed that the relationship between carapace length (*CL*) and body weight (*BW*) for males (*CL*, 5.84–14.10 cm) was $BW = 0.2598\ CL^{3.0931}$, and for females (*CL*, 5.35–10.97 cm) was $BW = 0.4280\ CL^{2.8656}$. Growth in each gender showed allometric growth. The average *CL* of males was significantly larger than that of females. Average male and female crab sizes in 1999 were smaller than in 1998. The spawning season was found to be from November to February; maturing male crabs were abundant from September to December. Average sizes of *CL* at first maturity for males and females were 7.44 and 7.22 cm, respectively. Fecundity ranges of ovigerous female crabs were 74 600–167 900 eggs with an average egg diameter of 0.62 mm. The monthly sex ratios (male : female) varied between 1:0.56 and 1:2.77.

KEY WORDS: **Andaman Sea, growth, *Ranina ranina*, red frog crab, reproduction.**

INTRODUCTION

The red frog crab, *Ranina ranina* (Linnaeus, 1758), lives on sand substrata in the offshore shelf throughout the tropical and subtropical Indo-Pacific region from the Seychelles Islands to Hawaii.[1] This species has been fished commercially around the Hawaiian Islands since before World War II.[2] In Australia, this species occurs from the Abrolhos Islands through northern tropical and Barrier Reef waters and as far south as southern New South Wales.[3] The red frog crab fishery in Australia has grown substantially in the 1980s, with almost 700 metric tons landed in Queensland and New South Wales from 1989 to 1990. Large specimens command very high prices, especially in live-seafood markets. Prices in Australia amount to about US$2–3 per kg, while live specimens in Hong Kong, China and Taiwan are sold for US$5–10 per kg.[4] The total annual catch in 1993 was estimated roughly at 1000 metric tons in Hawaii, Japan, Taiwan and Australia combined.[5] In Thai waters, it is abundant in the Andaman Sea at depths greater than 60 m. Red frog crab fisheries in Thailand have been in operation since 1997. The main fishing ground is in the areas of Thai-Myanmar boundary waters, Ko Surin, Ko Similan, and Ko Racha-noi. It is mainly harvested by bottom lift net (red frog crab gill net). In 1998, this fishing gear was improved in structure by the incorporation of a rectangular iron frame (1.51 m × 3.22 m). The improved apparatus greatly simplified harvest activities. The average catch was estimated at between 150 and 300 kg/boat per day. Most boats operated only in daytime with a working range of 25 days/month throughout the year. The catch was landed mainly at fishing ports in the areas of Ranong, Phang-nga and Phuket. Since the beginning of 1997, large sized living crabs have become an important fishery export to China, Taiwan, Japan and Singapore, while dead crabs are sold for consumption in local markets. The number of fishing boats rapidly decreased from 100 boats in 1997 to 20 boats in early 2000 as a result of resource deterioration due to overfishing. Some aspects of the reproductive biology of this species such as r mating behavior,[6,7] minimum size to maturity, the number of eggs attached to pleopods, and ovigerous season have been reported for populations from Hawaii,[8,9] the Philippines[10] and Australia,[11] but little information is available for populations from Thailand.

The objectives of this study were to investigate the crab's growth and reproductive biology in the Andaman Sea off Thailand. This information is cru-

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Received 23 May 2003. Accepted 14 July 2004.

cial for the future conservation, management and aquaculture of this species.

MATERIALS AND METHODS

A total of 1270 male and 2002 female crabs were sampled from gill nets which operated in the northern part of the Andaman Sea at depths of 60–90 m. Crabs were landed at Ban Thap Lamu, Lam Kaen Subdistrict, Thai Muang District, Phang-nga Province from January 1998 to December 1999 (Fig. 1). Wet body weight (*BW*), the carapace length (*CL*) and carapace width (*CW*) were measured for relative growth analysis.[12]

Gonadal weight (*GW*) was recorded and maturity stages were determined by visual observation after removal from the body by the modified method of Minagawa *et al*.[5,13]

The following stages were recognized for males: (i) in stage I (immature), the testes are small and tubular, slender and white. They are located under the carapace hypodermis and over the midgut gland near the heart; and (ii) in stage II (mature), the testes show increased size and have the form of two *Y*-shaped horns. They extend to the head region and their color is milk-white.

Female crabs were classified in the following stages: (i) in stage I (undeveloped), the ovaries are small, slender, tubular, and pale yellow. They are located at the same position as the male testes; (ii) in stage II (developing), the ovaries are yellow in color and extend to the anterior and posterior regions, forming an H-shape; (iii) at stage III (ripe), the ovaries increase in size. Inside, yellow eggs can be clearly distinguished but cannot be separated. The anterior ovarian portion begins to spread to the head region; (iv) in stage IV (spawning), the ovaries became dark orange or dark yellow and spread throughout the head region. They assume an *X*-shape. Eggs can be easily separated by manual dissection of the egg mass; and (v) in stage V (recovery), the ovaries decrease in size and become yellow or brown. The younger oocytes and the remaining eggs may be observed inside the ovary.

The eggs attached to the pleopods of ovigerous female crabs were fixed in Gilson's fluid[14] to examine fecundity[15] and its relationships with *CL*.[16] The number of eggs was estimated gravimetrically by wet-weighing and by counting the number of eggs in a sub-sample and multiplying it by the total wet weight of the egg mass. The gonadosomatic index (*GSI*) was calculated using the formula $GSI = GW \times 1000/BW$. Size at first maturity was determined as the smallest size of mature eggs observed[17] by modified methods of Minagawa *et al*.;[13] the size at which 50% of individuals mature was calculated by the method of Somerton.[18] The sex ratio at a 95% confidence level was examined by χ^2 test.

RESULTS

Relative growth

CL and *BW* ranged from 5.84 cm to 14.10 cm (mean ± SD, 9.38 ± 1.49 cm) and 50 g to 970 g in males while in females these values ranged from 5.35 cm to 10.97 cm (8.38 ± 0.88 cm) and 55 g to 420 g. The relationship between *CL* and *BW* were best described by the power equation as follows:

$$\text{male, } BW = 0.2598\ CL^{3.0931}$$

$$(r = 0.97,\ N = 1268),$$

$$\text{female, } BW = 0.4280\ CL^{2.8656}$$

$$(r = 0.94,\ N = 1999).$$

The relationships between *CW* and *CL* were best described by the linear regression equations as follows:

$$\text{male, } CL = 1.2463 + 1.0076\ CW$$

$$(r = 0.99,\ N = 1270),$$

$$\text{female, } CL = 1.2731 + 0.9970\ CW$$

$$(r = 0.96,\ N = 2002).$$

A significant difference was found between the length–weight relationship of males and females (ANCOVA, $P < 0.01$). Males were significantly larger than females (*t*-test, $P < 0.05$) and dominant in individuals over 9.5 cm *CL*.

Size-frequency distribution

Monthly changes in *CL* for each sex are shown in Figs 2 and 3. Small crabs appeared in March, June and August. The average size and maximum size of females was smaller than that of males for every month. Seasonal size fluctuation in both sexes was similar. Crab size in 1999 was smaller than that in 1998 for both males and females and this could be most clearly distinguished in July–December.

CL of ovigerous females ranged from 6.70 cm to 10.54 cm.

Spawning season

Maturity stages and mean *GSI* were calculated for sexually mature crabs and plotted for every month (Fig. 4). In females, most ovaries showed stage II

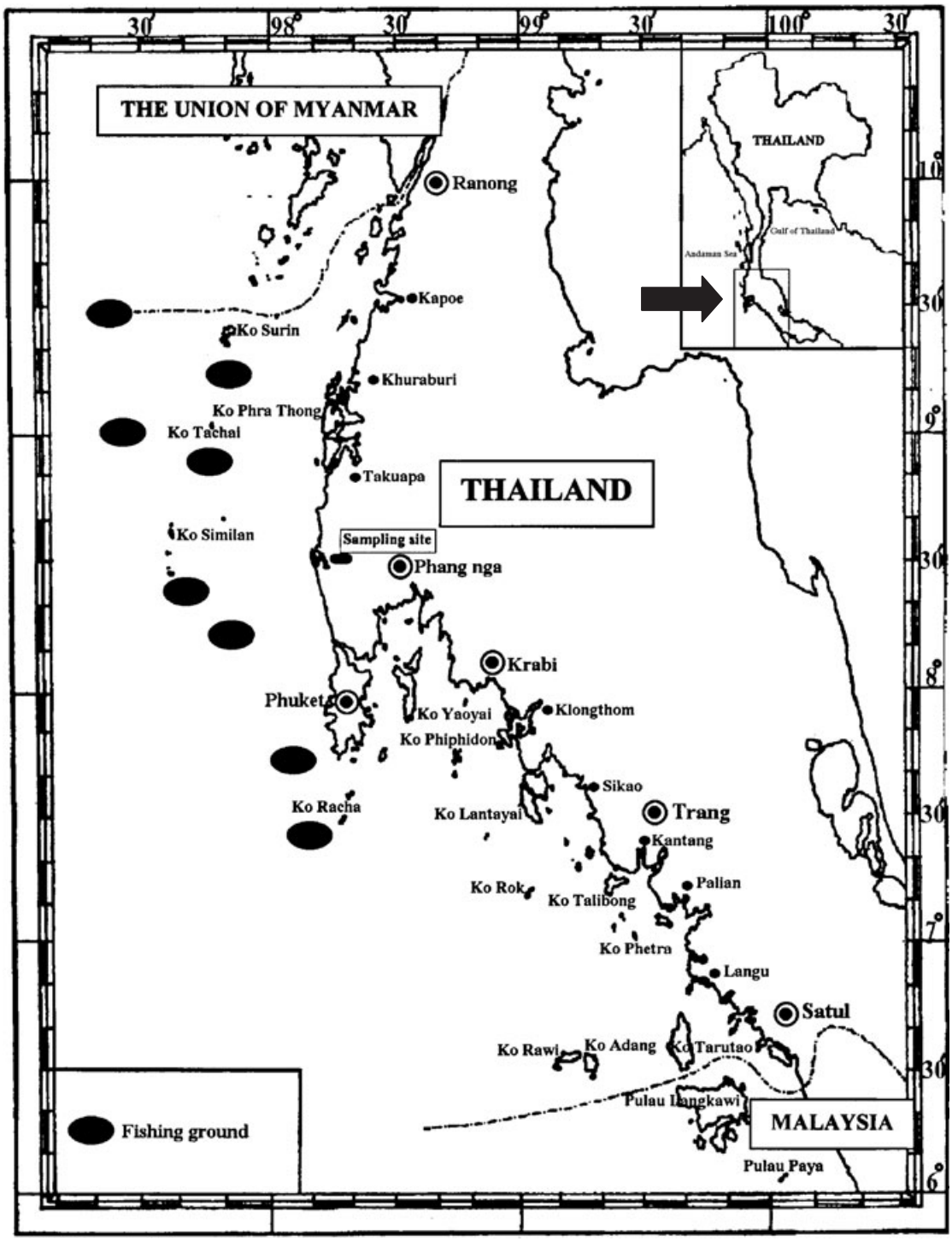

Fig. 1 Map showing the fishing ground of the red frog crab *Ranina ranina* in the Andaman Sea off Thailand.

and III, with the mean *GSI* value ranging from 8.6 to 38.0 from April to September. Between November and February, most ovaries showed stage IV. The mean *GSI* reached 84.7 in November 1998 and 67.7 in December 1999. Between January and February, the *GSI* decreased slightly, coinciding with the release of ova. Ovigerous females were found between November and May, but their occurrence peaked during the period from November to January (Figs 2 and 3). Testes were fully

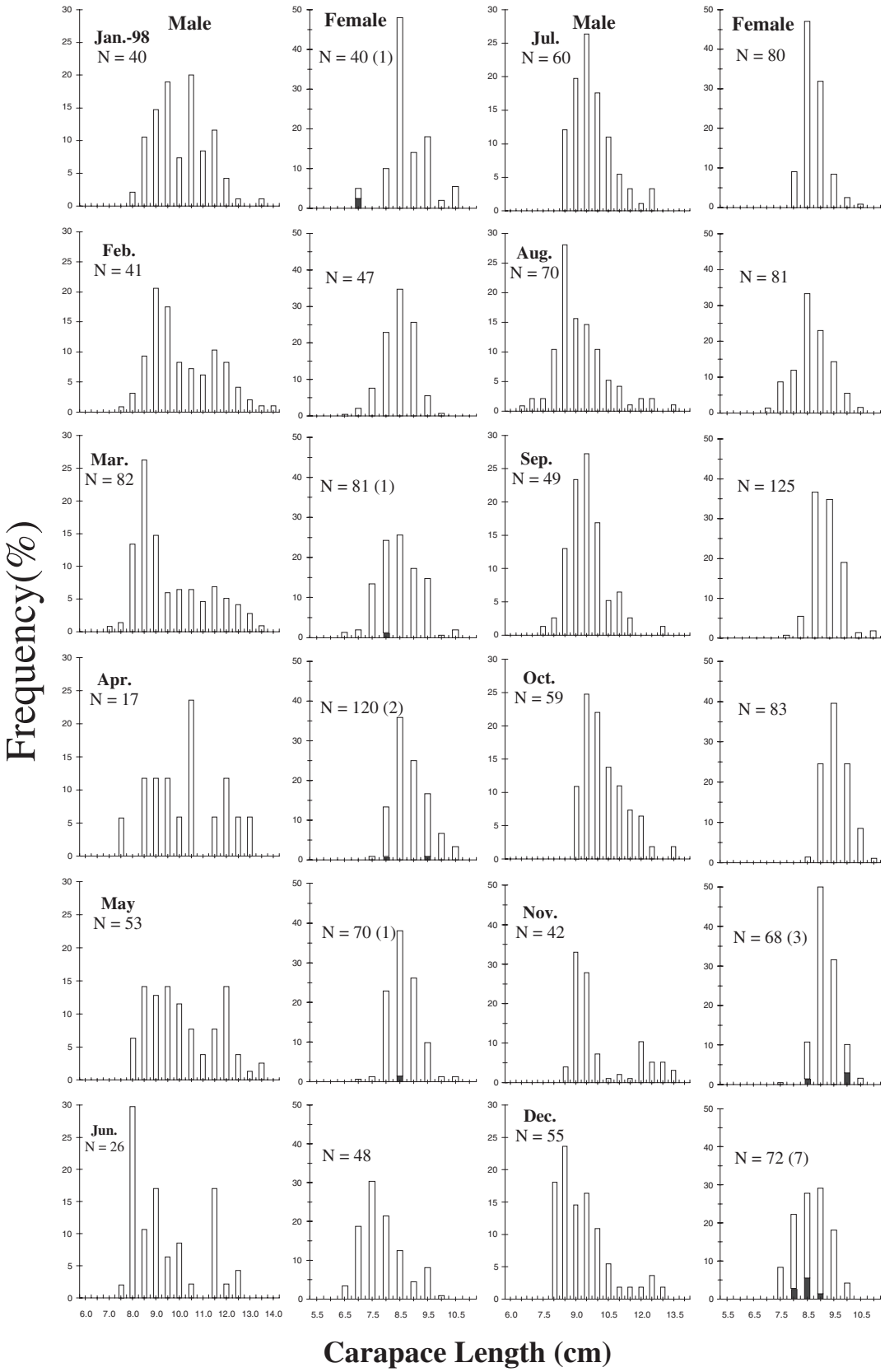

Fig. 2 Seasonal change in the size-frequency distribution of the red frog crab *Ranina ranina* in 1998. Figures in parentheses and black bars indicate ovigerous females.

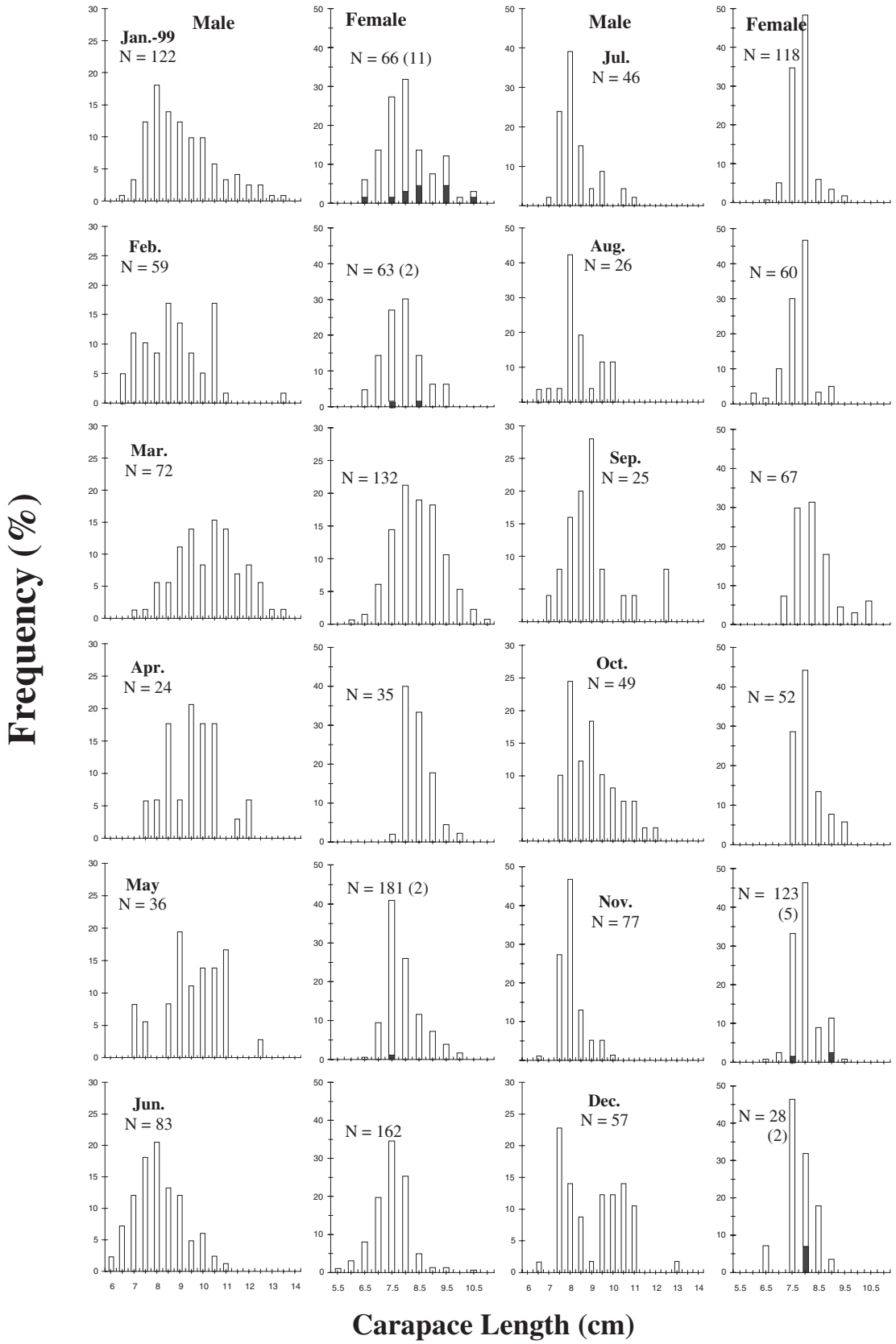

Fig. 3 Seasonal change in the size-frequency distribution of the red frog crab *Ranina ranina* in 1999. Figures in parentheses and black bars indicate ovigerous females.

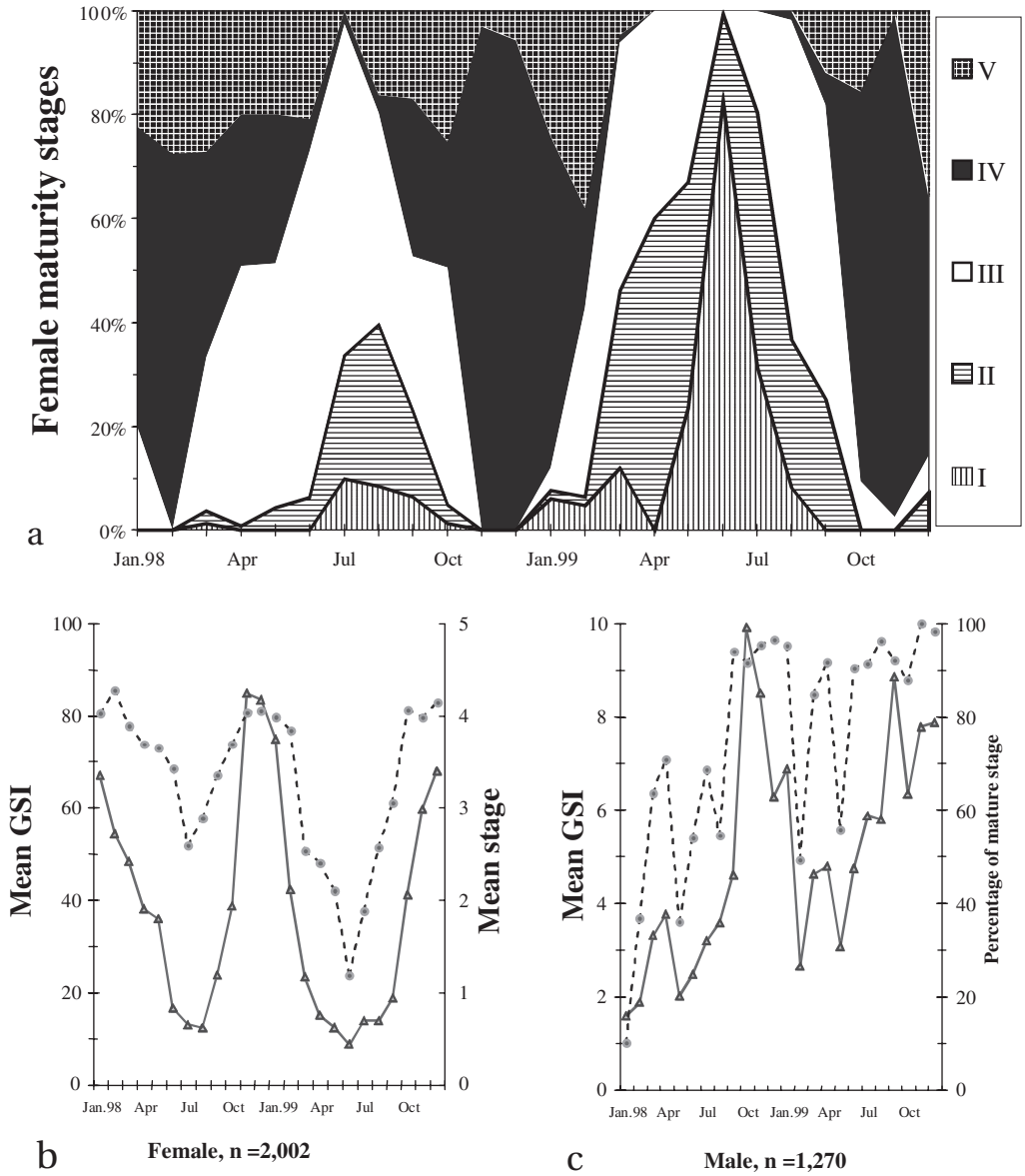

Fig. 4 (a) Percentage of female maturity stages (b) and mean gonadosomatic index (*GSI*) of females (C) and males of *Ranina ranina* from January 1998 to December 1999. Triangles and circles indicate *GSI* and percentage mature, respectively.

mature between September and December (mean *GSI* ranged from 4.6 to 9.9 in 1998, and from 6.3 to 8.9 in 1999; the mature stage ranged from 91.5 to 96.4% in 1998, and from 87.8 to 100% in 1999).

Size at first maturity

The smallest ovigerous female was 6.70 cm in *CL*, while the average *CL* of mature male and female crabs were 7.44 cm and 7.22 cm, respectively. The probability of sexual maturation (*Y*) from crab size was estimated by logistic equations as follows, taking in consideration the middle length of size class interval (*CL*, *X*):

$$\text{Male, } Y = 1/(1 + exp[5.5739 - 0.7494X]),$$

$$\text{Female, } Y = 1/(1 + exp[5.6217 - 0.7789X]).$$

Fecundity

The number of eggs per egg mass on pleopods was estimated from five ovigerous females ranging

from 8.7 cm to 10.1 cm *CL*, and from 220 to 410 g *BW*. Fecundity ranged from 74 600 to 167 900 eggs (mean ± SD of 104 060.80 ± 38 294.24 eggs), with an average egg diameter of 0.62 mm. The relationship between fecundity (*F*) and *CL* was best described by the power equation as follows:

$$F = 5.1151\ CL^{4.4939}$$

$$(r = 0.37,\ N = 5).$$

Sex ratio

The monthly sex ratio (male : female) varied dramatically between 1:0.56 and 1:2.77 throughout the year. Most monthly ratios were significantly different from 1:1. The overall sex ratio (for the entire period of 24 months) was significantly different from the expected 1:1 ratio (χ^2 test, $P < 0.05$), with females being 1.5-fold more abundant than males. However, in January and March 1998 as well as January and December 1999, there were almost twice as many males as females (Fig. 5).

Sex ratios in accordance with *CL* showed a significant deviation from the expected 1:1 ratio in every size bracket (except *CL* ranged from 12.5 to 14.5 cm which was found only in males), dropping slowly from 1:3.25 to 1:0.02 ratios (Fig. 6). For instance, there were threefold as many females as males in the 5.5 cm and 6.5 cm *CL* classes, twice as many females as males in the 7.5 cm to 8.5 cm brackets, and 1.5-fold as many females in the 9.5 cm class, but in excess of three males for each female in larger size categories.

DISCUSSION

Males were generally larger than females, so males apparently grow faster than females. This was also evident from the comparison of the length–weight relationship between males and females, which showed a significant difference in the specific growth rates. These results conformed to the results of Brown[11] but differed from those of Minagawa.[19]

As in our study, Brown[11] reported that the difference between the slopes of the regression for males and females was highly significant. Moreover, the slope for females and males was significantly different from three, indicating that in neither sex the weight and length are isometrically related. In contrast, Minagawa[19] showed that the relationship between *CL* and *BW* was similar in both sexes.

In the present study, ovigerous females were found between November and February. Thus, it may be concluded that this crab spawn during this period. The frequency of ovigerous females peaked at about the same time in southern Queensland.[11] These results conform with observations of Rice and Ingle,[20] who pointed out that the reproductive cycle in the Southern Pacific is similar to that of Southern Indian Ocean stocks. In Japan, this crab spawns between June and August. This discrepancy may be related to the difference in latitude, since, as suggested by Onizuka,[8] Fielding and Haley,[9] and Sakai,[21] spawning takes place earlier in lower latitudes.

Our estimation of fecundity agreed well with the results of Brown[11] and Holden and Rait.[15]

The number of females greatly exceeded that of males in crabs captured in the Andaman Sea, a result which is different from those of Brown,[11] Onizuka,[8] and Fielding and Haley.[9] There were more males than females in Australian and

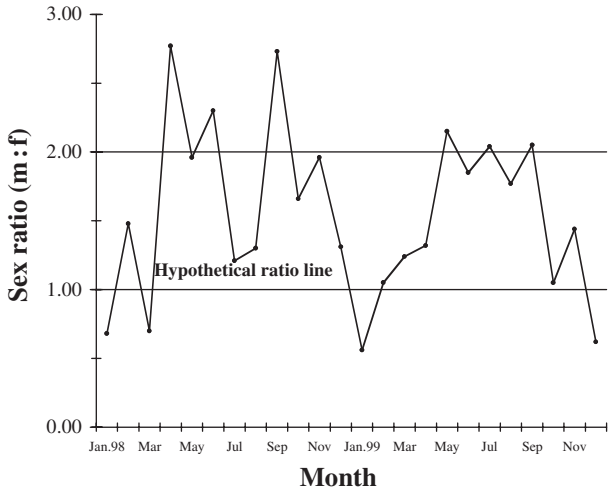

Fig. 5 Sex ratio of males to females for the red frog crab *Ranina ranina* in 1998 and 1999.

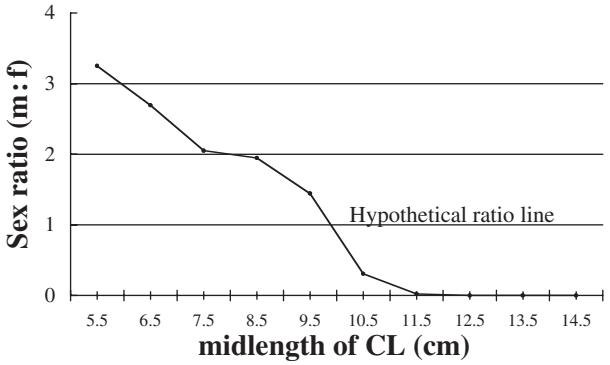

Fig. 6 Sex ratios and carapace length of the red frog crab *Ranina ranina*.

Hawaiian crab stocks. Selection by the fishermen of live crabs for selling to foreign markets might have introduced a sampling error because only data for dead crabs was used in the present study. We were not allowed to measure live crabs because they were already weakened by the harvesting and transportation.

The total catch of this crab from 1997 to 2000 was more than 1000 metric tons. The landing at Phuket Fish Marketing Organization from April 1997 to October 2000 was approximately 329 metric tons. The highest landing of 127.6 metric tons was recorded in 1998. After that, landings decreased to 50.9 metric tons in 2000 (Fig. 7). This was the catch from boats operated around the areas of Ko Rachanoi and western Phuket. The exported quantity from Phuket International Airport during August 1998 to March 1999 (8 months) summed to approximately 560 metric tons, worth about 33.6 million baht.

Thus, the fishery's condition appears to be declining, perhaps as a result of the unsustainably-high yield. This impact will automatically cause a decrease in the number of fishing boats. A more serious problem could be the apparent decrease in the average size of crab, compared to previous years. Good conservation and the development of aquaculture using the results of breeding and nursing studies will be essential for the maintenance of a sustainable fishery in the future. From this perspective, one recommendation would be to enact capture prohibition during the spawning season, especially from November to January, as evidenced by the high frequency of ovigerous females during this period.

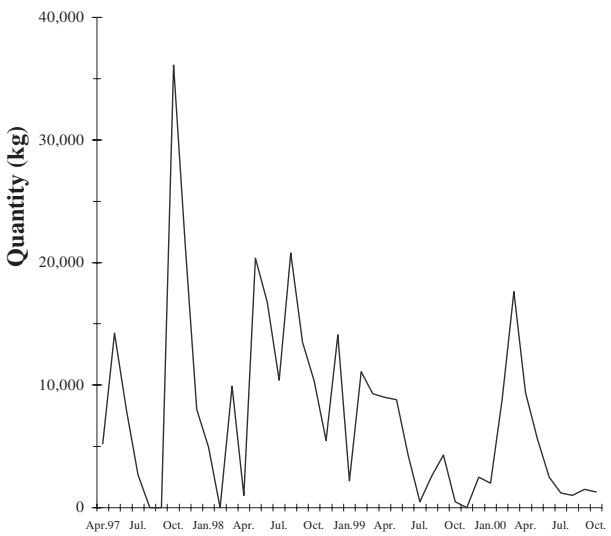

Fig. 7 Landing of the red frog crab *Ranina ranina* at Phuket Fish Marketing Organization from April 1997 to October 2000.

ACKNOWLEDGMENTS

The authors wish to thank Mr P Sutthakorn (Director of Andaman Sea Fisheries Development Center) and Assistant Prof Temp. C Chuensri (Department of Marine Science, Faculty of Fisheries, Kasetsart University) for valuable advice and comments on the manuscript. They also thank Mrs B Jaruthamsophon (Marine Life History Unit, Andaman Sea Fisheries Development Center) and Mr W Janekarn (Phuket Marine Biological Center) for reading the manuscript critically. Lastly, the authors appreciate efforts of the Andaman Sea Fisheries Development Center staff and many others in collecting data and crabs.

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