

Reproductive Biology of the Red Frog Crab, *Ranina ranina* (Linnaeus, 1758) (Crustacea: Decapoda: Raninidae) from Southwestern Mindanao, Philippines

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Abstract

The red frog crab (*Ranina ranina* (Linnaeus, 1758), Ranididae) is an important fishery resource in the Philippines and may have potential for aquaculture and stock enhancement. To determine basic reproductive information for the species in the Philippines, a one-year study was conducted of the red frog crab from southwestern Mindanao, Philippines. In both sexes, gonad activity occurred throughout the year but for females the peak egg bearing season was November to February (59-87% ovigerous). Body sizes of ovigerous females were from 61.9 - 148.2 mm carapace length (CL). The greatest prevalence of ovigerous females was in the size range of 90–99 mm CL; the lowest at 140–149 mm CL. Male crabs with mature testes were consistently high (83-100%) in all months of the year. Females had higher gonadosomatic indices (GSI), 4.90–26.64, compared to those of the males which were 1.77–5.36. Gonad indices (GI) varied from 1.77-2.9 for females and from 1.83 to 2.0 for males. The smallest female carrying eggs was 61.9 mm CL and the smallest male with a mature gonad was 40.23 mm CL. The number of eggs (fecundity) per egg mass ranged from 26,225-354,084 eggs individual⁻¹.

Introduction

The red frog crab or spanner crab *Ranina ranina*, (Linnaeus, 1758) belonging to the family Raninidae and locally known as “curacha”, is an important edible crab. It is abundant in the coastal waters of southwestern Mindanao, Philippines. These crabs are also found in the eastern coast of Africa, across the Indian Ocean to Indonesia, Australia, Japan and Hawaii. The largest commercial fishery of this crab is on the eastern coast of Australia where the annual commercial catch is estimated at 3,592 tonnes (Queensland Fisheries, 2010). They are found in depths of 10–100 m on sandy-smooth substrata in which they bury (Tahil, 1983; Kennelly, 1992). To feed, they ambush small fish and other organisms from their hiding places in the sand (Kennelly and Watkins, 1994). They are caught using baited traps made of tangle-nets suspended over flat frames (Tahil, 1983; Kennelly and Watkins, 1994). In Mindanao, they are available year round and in 2010, their price ranges from P300-350 kg⁻¹, depending on size and abundance.

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As a highly priced food commodity, *R. ranina* is a potential species for aquaculture, domestication and stock enhancement. Aspects of its reproductive biology, minimum size at maturity, fecundity and breeding season have been reported for populations from Hawaii (Fielding and Haley, 1976), Japan (Minagawa et al. 1993), Australia (Kennelly and Watkins, 1994), and Thailand (Krajangdara and Watanabe, 2005). In the Philippines, the only record of its reproductive biology was from Tabil (1983) in central Tawi-Tawi. A more recent study was carried out on some aspects of the fisheries and biology in Maluso, Basilan Province but the data were incomplete (Tito and Alanano, 2008). Larviculture of the red frog crab has been attempted in Kagoshima Prefectural Mariculture Center in Japan (Minagawa et al. 1993). However, mass culture has not yet been successful and therefore the present study was designed to find out more about their reproduction in the Philippines.

This present investigation aimed to determine the breeding cycle, size composition and size frequency distribution of ovigerous females, fecundity and minimum size at sexual maturity of the *R. ranina* crab population collected from the fishing grounds off the islands of southwestern Mindanao, Philippines. This information could be valuable in the conservation and implementation of regulatory measures for wild stock management as well as for future culture and domestication.

Materials and Methods

Collection of samples

A one-year survey, from January to December 2009, was conducted to determine the breeding cycle and reproductive biology of *R. ranina*. Every day, crabs delivered to Zamboanga city markets were sexed, measured and examined if carrying eggs (ovigerous) or not. These crabs represented 30% of total red frog crab landings from all fishing grounds in southwestern Mindanao (Tito and Alanano, 2008). Every 2nd week of the month, crab samples were obtained with representatives from both sexes and from different size groups, for the determination of fecundity and gonad development stages. Crabs that were examined for fecundity and gonad development stages were caught from Sakol Island while the females that were examined for egg-bearing state (ovigerous) were crabs that were caught from all fishing grounds in southwestern Mindanao and brought to Zamboanga city markets. The crabs delivered from Sakol Island had intact egg masses while those from other sources were delivered through the normal market chain and tended to be damaged due to handling during transport and storage. Preliminary sorting was done in all fishing grounds except Sakol Island. Smaller crabs were removed from the catch before delivery to the markets. In 2009, as part of our study on the fishery and stock assessment of *R. ranina* in southwestern Mindanao, we identified 12 fishing grounds that supply the local markets in Zamboanga City. These included the islands and islets in the coastal waters of Zamboanga Peninsula and the provinces of Basilan, Sulu and Tawi-Tawi.

Crabs were classified as males or females based on the shape of their abdomens. Body weight (BW) was measured using vernier calipers. Body size was measured as carapace length (CL), determined by the distance from the posterior edge of the eye orbit to the posterior edge of the carapace (Kennelly and Watkins, 1994). Total body, egg mass and gonad weights (g) were recorded to the nearest 0.01 g using a digital electronic balance. Gonad developmental stage was determined through visual examination after removing the dorsal carapace of the crab (Krajangdara and Watanabe, 2005).

Gonad analysis

The quantitative gonadosomatic index (GSI) was calculated using the equation: $GSI = \text{gonad weight (g)} / \text{body weight (g)} \times 1000$ (Krajangdara and Watanabe, 2005). Prior to the computations of the gonad indices (index of sexual maturity), pre-weighted values (WV) were assigned to the female gonad stages as: undeveloped and recovering - 1, developing - 2, ripe and spawning - 3. For the male testes, the values assigned were: immature - 1, and mature - 2. The mean value of gonad indices (GI) were then calculated using the equation: $GI = \Sigma(n \times WV) / N$, where n is the number of individuals in a given developmental stage; WV is the pre-weighted value for the developmental stage; and N is the total number of crabs per monthly sample. Values of mean monthly indices were then plotted against time (months) to determine the spawning pattern or reproductive cycle. Analysis of the gonad stages was supplemented by the quantitative and qualitative estimation of the gonad indices.

Fecundity

Fecundity is an index of reproductive capacity and is estimated by the number of eggs produced by an organism (Reeby et al. 1990). The mean number of eggs per egg mass was determined by scraping off all the eggs attached to the pleopods of ovigerous females. Three replicates of 1 g sub-samples were taken and the number of eggs in each replicate was counted under a dissecting microscope. To estimate the fecundity of each female crab, the mean number of eggs in the three replicates was multiplied by the total wet weight of the egg mass (Krajangdara and Watanabe, 2005). Regression analysis was conducted to show the relationship of fecundity versus size of the female crab.

Results

Occurrence of ovigerous females

A total of 7,650 female crabs were examined to determine the monthly percentage incidence of ovigerous females (Fig. 1). Berried females were found all year round although the peak of the spawning season, when more than 50% of the females were ovigerous, started in November and continued until February. The incidence of ovigerous females was only 18% in October but rose to 69% in November and was highest at 88% in December after which it began declining.

Size composition and size frequency distribution of ovigerous females

The size of the ovigerous females (CL) ranged from 61.90-148.2 mm, with an average of 94.6 mm (Fig. 2). The greatest percentage of females carrying eggs occurred in the size range 90–99 mm CL. The lowest percentage of females with eggs was for the size range 140–149 mm CL.

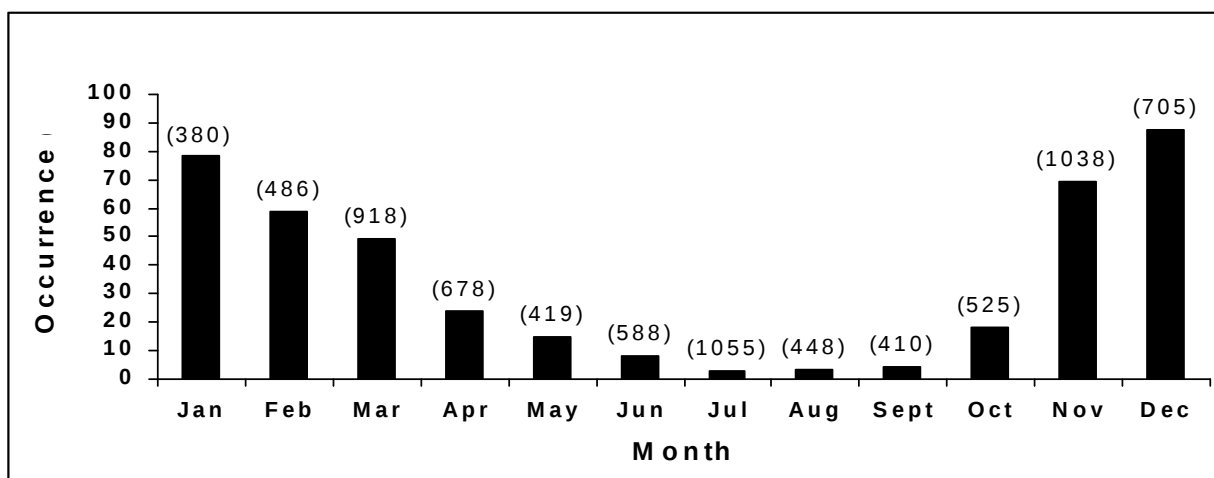


Fig 1. Monthly occurrence (%) of ovigerous *R. ranina* females from southwestern Mindanao, Philippines, Jan – Dec 2009 (n=7,650). Numbers in parentheses indicate numbers in the monthly samples.

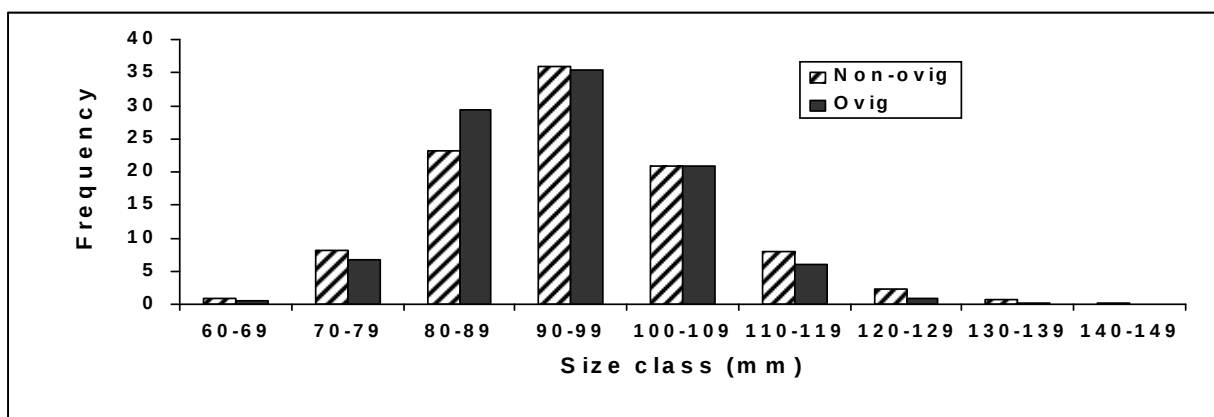


Fig 2. Size composition and size frequency distribution (%) of ovigerous and non-ovigerous *R. ranina* females from southwestern Mindanao, Philippines, Jan – Dec 2009 (n=7,650).

Breeding season

The percentage of gonad development stages and mean monthly GI of female *R. ranina* is shown in Fig. 3. A total of 126 females were examined. In January, a small percentage of gonads (6.7%) were ripe, but many gonads were in undeveloped, developing and spawning stages. No gonads were in recovery stage. In February, the percentage of ripe gonads increased to 44.4% and a peak of 50% was obtained in March. The March peak coincided with an increase in the GSI (Fig. 5). In April, the percentage of ripe gonads dropped to 11.1% and the decline continued to July. This coincided with lower GSIs from April to June. Starting in July and continuing to December, the number of gonads (33.3-50%) in spawning stage increased. This was complemented by an increasing GSI for these months. The lower GSI in November coincided with the start of the spawning season, where ripe eggs were extruded from the ovaries. This was the month when up to 69% of the females in the market were carrying eggs (ovigerous).

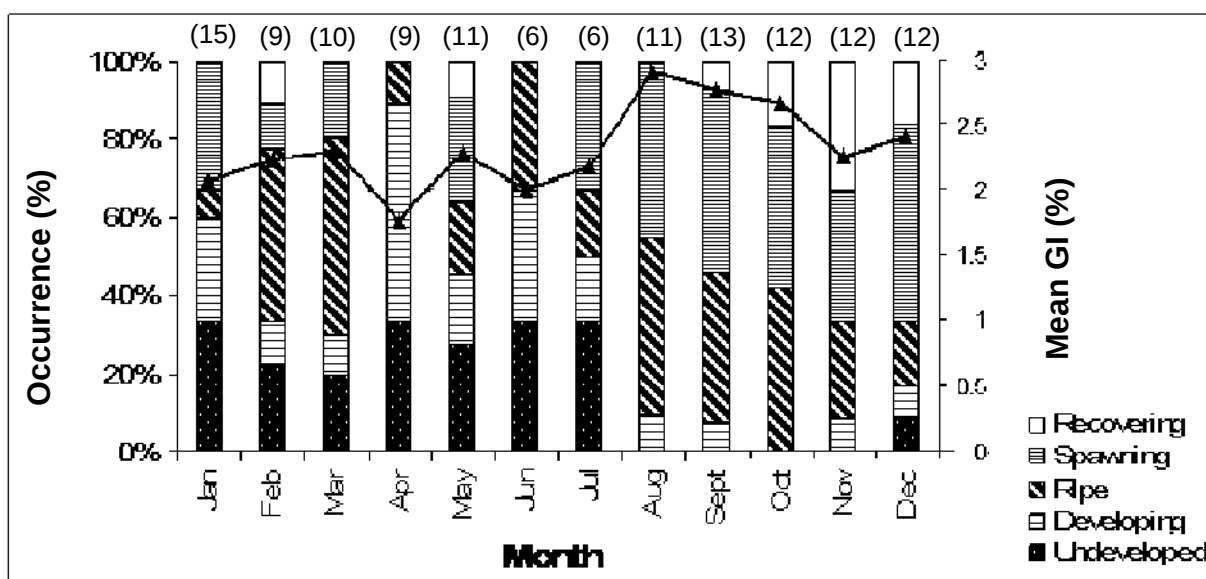


Fig 3. Monthly occurrence (%) of gonad development stages and mean gonad index (GI) (%) of female *R. ranina* from southwestern Mindanao, Philippines, Jan – Dec 2009 (n=126). Numbers in parentheses indicate numbers in the monthly samples.

A total of 110 males were examined for gonad development. The occurrence of mature testes was high (83 - 100%) in all months of the year while immature gonads were obtained only in February and June (Fig. 4). The presence of mature male gonads throughout the year was supported by a GI that showed minimal variation with month.

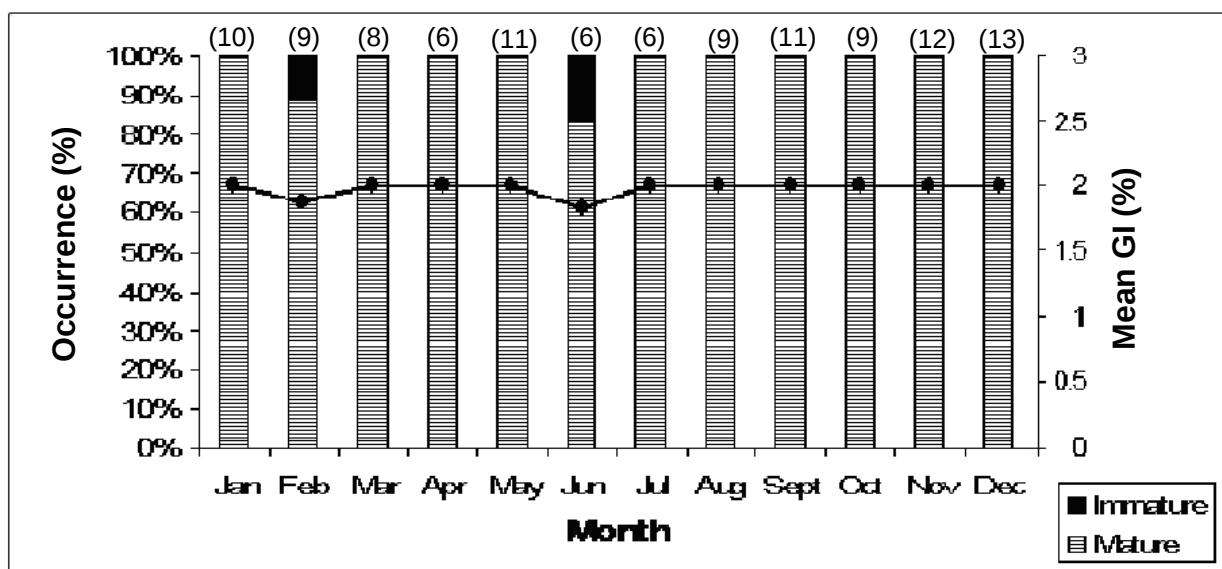


Fig 4. Monthly occurrence (%) of gonad development stages and mean gonad index (GI) (%) of male *R. ranina* from southwestern Mindanao, Philippines, Jan – Dec 2009 (n=110). Numbers in parentheses indicate numbers in the monthly samples.

Gonadosomatic Index (GSI)

The GSI is a measure of the reproductive condition of a population. In females, monthly GSI were fluctuating (Fig 5). There was an increasing GSI from January to March, followed by a decline in April with the lowest GSI obtained in June. The GSI rose in July and reached its peak in September. The GSI declined in October and November but rose again in December. The low values corresponded to months when gonads were in early stages of development (undeveloped, developing) or recovering. The high values coincided with months when most of the gonads were in later stages of maturation (ripe, spawning).

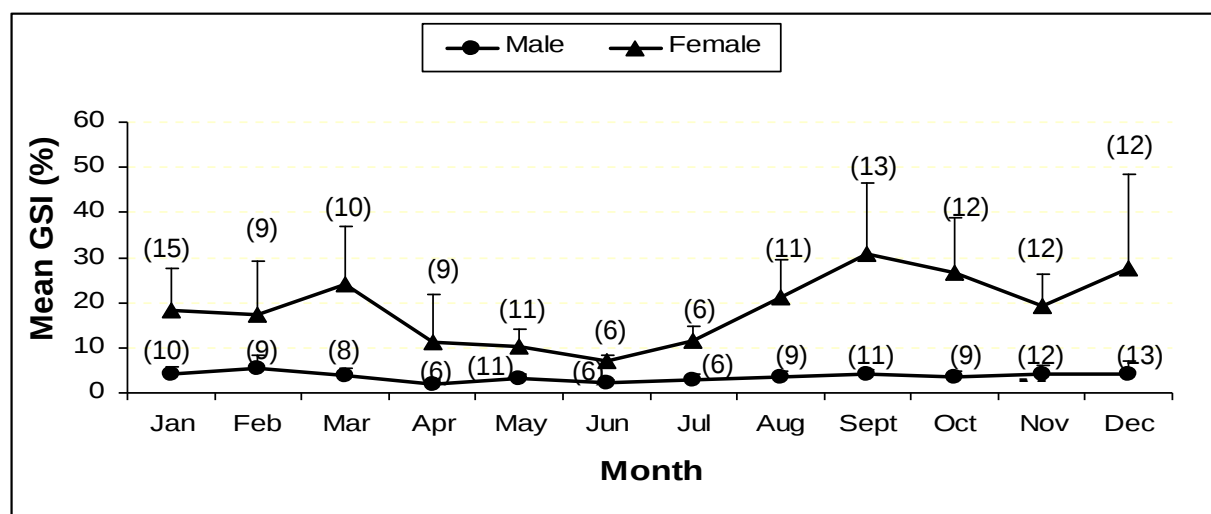


Fig 5. Monthly gonadosomatic index (GSI) of male and female *R. ranina* from southwestern Mindanao, Philippines, Jan–Dec 2009 (Female=126; Male=110). Vertical bars indicate standard deviations. Numbers in parentheses indicate numbers in the monthly samples.

In males, mean GSI ranged from 1.8 to 5.4. Unlike that of the females, the monthly variation of GSI was very minimal. Overall, the females (4.9–26.6) have higher quantitative GSI compared to the males (1.8–5.4). The ovaries of the females make up a bigger portion of the individuals' total weight, in contrast to the testes of the males.

Gonad Index (GI)

Gonad index is a measure of sexual maturity of a population. The GI values ranged from 1.8–2.9 for females and 1.8–2.0 for males. The monthly variations in gonad indices of females and males are shown in Figs. 3 and 4. In females, high values coincided with months when most of the gonads were in later stages of maturation (ripe, spawning) while low values corresponded to months when gonads were either in early stages of development (undeveloped, developing) or recovering. The highest value (2.9) was obtained in August while the lowest value (1.8) was obtained in April. In males, high values corresponded to months when gonads were mature and low values corresponded to months when some testes were immature.

Minimum size at sexual maturity

The size range of females sampled was 60–149 mm. The smallest *R. ranina* female carrying eggs was 61.9 mm CL. The biggest ovigerous female was 148.2 mm CL. For the male *R. ranina*, the smallest crab with a mature gonad was 40.23 mm CL.

Fecundity

Twenty-nine females with body size of 71.50-127.30 mm CL and with wet egg mass weight range of 5.5-44.6 g, were examined. The fecundity counts varied from 26,225 to 354,084 eggs individual⁻¹.

Discussion

In the present study, the year round gonad activity of female *R. ranina* with peaks in November to February, is similar to that for the reproductive period of *R. ranina* collected from central Tawi-Tawi, Philippines where it was reported that although ovigerous crabs were present all year round, the highest incidence of females carrying eggs occurred from October to February (Tahil, 1983). However, the crabs in Tawi-Tawi started their reproductive season one month early (October) compared to those in the present study where the reproductive season started in November. The difference may have been due to different sampling strategies and/or different oceanographic conditions between the years of the different studies. In Tahil's (1983) study, crab samples for the reproductive biology were taken from the daily catch, while in this present study, sampling was done every 2nd week of the month. In both studies, the peak of the spawning season ended in February.

As reported in the few available studies, the breeding season of *R. ranina* may vary between regions (Fig 6). In Hachijojima, Japan, 10-90% of the females were ovigerous in May to September with the highest number of berried females in June (Minagawa et al. 1993). Similarly, in Molokai, Hawaii, an average of 86% of the females were found to be ovigerous from May to September (Fielding and Haley, 1976). In both regions, no ovigerous females were found during the remaining months of the year. In the Andaman Sea, Thailand, only 1.1% -16.6% of *R. ranina* females were carrying eggs in November to May with peaks in November to February (Krajangdara and Watanabe, 2005). In northern New South Wales, Australia, 30-80% of spanner crab females were ovigerous in December but since the survey was done only every two months, it was possible that females may have been ovigerous between November and January each year (Kennelly and Watkins, 1994). This finding was similar to the reproductive period reported by Skinner and Hill (1986) for *R. ranina* samples from Queensland, Australia. Generally in Australia, spanner crabs spawn during the warmer months of the year from October to February (Kailola et al. 1993). In summary, the peak season for ovigerous females corresponded with that found in previous tropical studies in Thailand and the Philippines, and also in temperate Australia and was the reverse of that in Japan and Hawaii, suggesting that seasonality in the reproductive cycle in each region may be due to seasonal fluctuations in ocean conditions other than temperature. These include salinity, light, currents and availability of food for the larvae (Batoy et al. 1987).

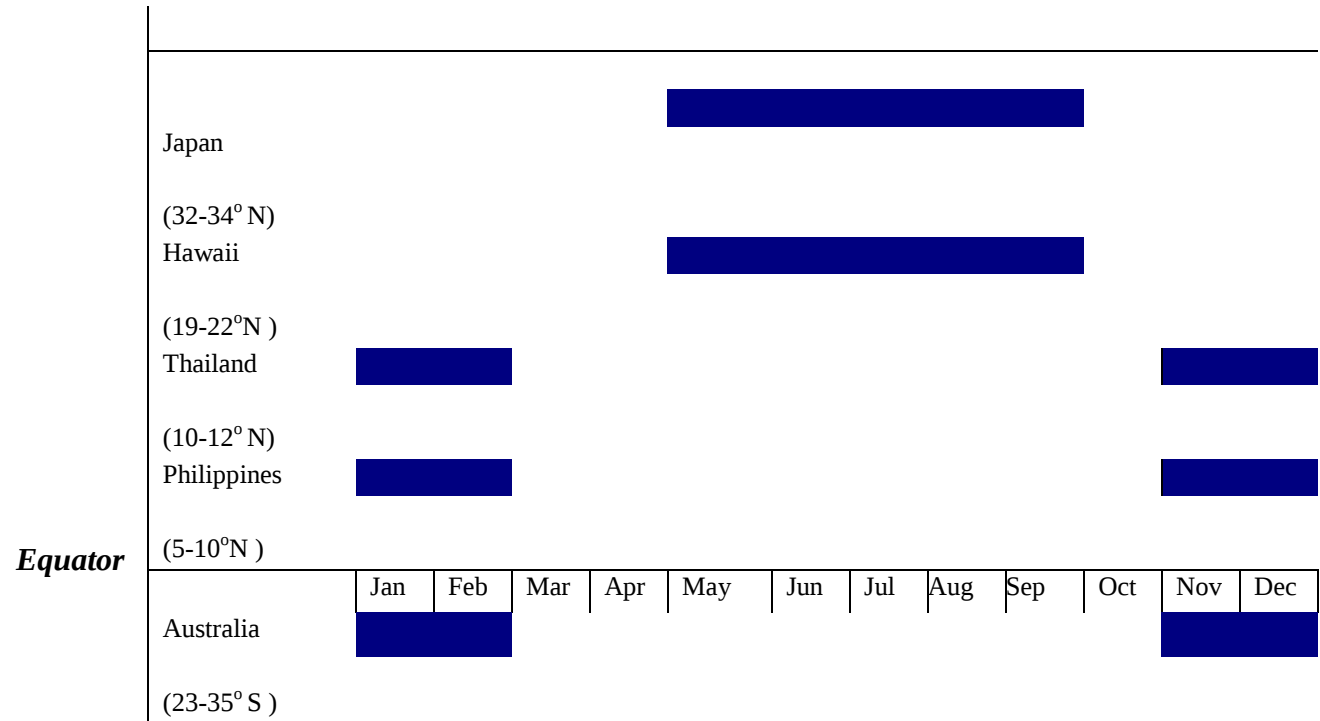
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Fig 6. Differences in spawning season between the different populations of *R. ranina*, as indicated by a monthly 10-90% ovigerous females in Hachiojima Japan; 86% ovigerous females in Molokai, Hawaii; 1-17% ovigerous females in the Andaman Sea, Thailand; greater than 50% ovigerous females in Mindanao, Philippines; and 30-80% ovigerous females in New South Wales, Australia.

In any one month in the present study, ovigerous females when dissected, had gonads in different stages of development from stages I-V, which suggests heterogeneity of the breeding population (Batoy et al. 1987). This present finding on *R. ranina* is consistent with the observation that breeding in tropical crabs is often continuous throughout the year (Warner, 1977).

The smallest *R. ranina* female carrying eggs was 61.9 mm CL. This present finding on the minimum size at sexual maturity of females, is comparable to that reported in other regions. In Hawaii, females with CL greater than 54 mm CL had developing ovaries and/or were ovigerous (Fielding and Haley, 1976). In Hachiojima, Izu Islands, Japan, the smallest size of sexually mature *R. ranina* female was between 50 and 60 mm CL (Minagawa et al. 1993) while in the Andaman Sea, Thailand, it was 67 mm CL (Krajangdara and Watanabe, 2005). In Australia, females mature at 70-75 mm CL although egg-bearing females as small as 64 mm CL had been recorded (Brown, 1986).

For the male *R. ranina*, the smallest crab that was found to have a mature gonad was 40.2 mm CL. Almost all of the male crabs that were examined had gonads at a mature stage and few samples had male crabs with immature gonads. However, the smallest size at sexual maturity for both male and female crabs in Mindanao may be even smaller considering, since the samples were dependent only on crabs obtained from the markets and selected to be the larger marketable specimens.

Fecundity ranged from 26,225- 354,084 eggs per female. Regression analysis showed that fecundity increased as CL of the female crab increased. The high variation in the number of eggs per brood was similarly reported on *R. ranina* females caught in other regions. For crabs caught in the waters of Hawaii, the number of eggs per brood ranged from 30,000-230,000 (Fielding and Haley, 1976); 78,000-256,000 in Australia (Kennelly and Watkins, 1994) and 74,600-167,900 in Thailand (Krajangdara and Watanabe, 2005). It was also observed that berried *R. ranina* in captivity had larger egg masses during the first spawning, compared to the second spawning. Large *R. ranina* females are able to produce at least two batches of eggs each season, from a single mating (Fielding and Haley, 1976; Minagawa et al. 1993; Kennelly and Watkins; 1994). Multiple spawnings from a single mating and a decrease in the size of the egg masses on later spawnings had been similarly observed in portunid crabs such as *Scylla serrata*, *Portunus pelagicus* and *Charybdis feriatus* (Baylon, 2007).

Conclusion

The results of the present study on the reproductive biology of *R. ranina* will be valuable for its conservation, management and possible hatchery operation. Gonad activity was continuous throughout the year making them potential species for culture because broodstock is always available. Development of hatchery technology for this species may be needed for the maintenance of a sustainable fishery in the future unless wild stocks are managed. The information on the reproductive biology will be helpful in determining seasonal closures on the capture of females during peaks of their spawning activity, especially the large females which carry the greatest number of eggs.

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