Research Article

Biological information on the mantis shrimp, *Harpiosquilla raphidea* (Fabricius 1798) (Stomatopoda, Crustacea) in Indonesia with a highlight of its reproductive aspects[1]

Yusli Wardiatno* and Ali Mashar

*Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University (IPB), Kampus IPB Darmaga, Bogor 16680, Indonesia. *email: ywardiatno@hotmail.com*

ABSTRACT. We conducted a study on the biology of mantis shrimp *Harpiosquilla raphidea* collected from a mudflat at the mouth of Tungkal River, Jambi Province, Indonesia. Some biological information is described such as sex ratio, size frequency distribution of the population, and gonad maturity stage of females. Gonad development was also observed in a laboratory. The results showed that for the entire population, the sex ratio was female biased. Three stages of gonad maturity occurred in the population indicating continual breeding. Based on the laboratory observation, shrimp collected from the field started to develop gonad within two weeks.

Keywords: mantis shrimp, reproductive biology, mudflat

INTRODUCTION

From a fisheries point of view, macrobenthic communities of demersal invertebrates and fish in marine soft-sediment have long been recognised as important resources in global fisheries, especially in Asia (Colloca *et al*., 2003; Garces *et al*., 2006; Lui *et al*., 2007). In these communities, many species of mantis shrimp are commercially valuable, such as *Oratosquilla oratoria* (Kodama *et al*., 2004) and *Squilla* sp. (Musa & Wei, 2008). Mantis shrimp can be found regularly in fish markets in several countries, such as Spain, Italy, Egypt and Morocco (Abello & Martin, 1993).

Ecologically, mantis shrimps are one of the most conspicuous members of the littoral and sublittoral large-sized benthic animals living in soft sediments worldwide. These organisms reside in their burrows for shelter, reproduction and feeding. The spearer mantis shrimp, *Harphiosquilla raphidea* lives on muddy bottoms in coastal waters around Indonesia. In a mudflat developed in the mouth of the Tungkal river in the Jambi Province, the shrimp is exploited commercially, mainly by small bottom-trawlers and gill nets due to its economical value. Live mantis shrimp caught by the fishermen costs around USD 3.5 per individual with a 7–9 inch size (pers. observations, 2009). The shrimp is mostly exported to Hong Kong and Taiwan, and demand continues to increase over the years.

To avoid the extinction of the shrimp due to exploitation, domestication of wild population is an alternative. For this, information on the biology of the shrimp is needed. This paper presents information on the biology of *Harpiosquilla raphidea* with a highlight its reproductive aspects.

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MATERIALS AND METHODS

Study area

The present study was carried out on an intertidal mudflat developed at the mouth of Tungkal River, Tanjung Jabung Barat District, Jambi Province (Figure 1). At extreme low spring tides, the mudflat is exposed for 1 km seawards. *Harpiosquilla raphidea* occurs over almost the entire mudflat. The depth of the sediment column was at least 50 cm, and could probably reach more than 2 metres. The water characteristics are as follows: temperature ranged from 28.2 ^{o}C to 30.5 ^{o}C, salinity ranged from 15 to 19 psu, and oxygen concentration ranged from 6.7–7.6 ppm.

Sampling of *Harpiosquilla raphidea*

Sampling of the *Harpiosquilla raphidea* was conducted on 15–20 November 2009. Sample collections were made using commercial gill net 4-inch as directed by a local fisherman. Collected shrimps were measured to obtain the Kubo's body length [abbreviated as BL: from the base of the rostrum to the anterior edge of the median notch of the telson (Ohtomi *et al*., 1992; Kubo *et al*., 1959)]. Measurements were made to the nearest 0.1 cm using a caliper. Sex was determined by the presence or absence of penis located at the base of a pair of third pereiopods on the eighth thoracic segment (Kubo *et al*., 1959), unless evident by the conspicuous presence of ovaries in females. Gonad maturity of the females was determined by the cement gland development which is visible through the exoskeleton on the sixth, seventh, and eighth thoracic sternites. The development could be divided into three stages: (a) stage 1– no gland development and no ventral "stripes", (b) stage 2– gland development into three parallel lines

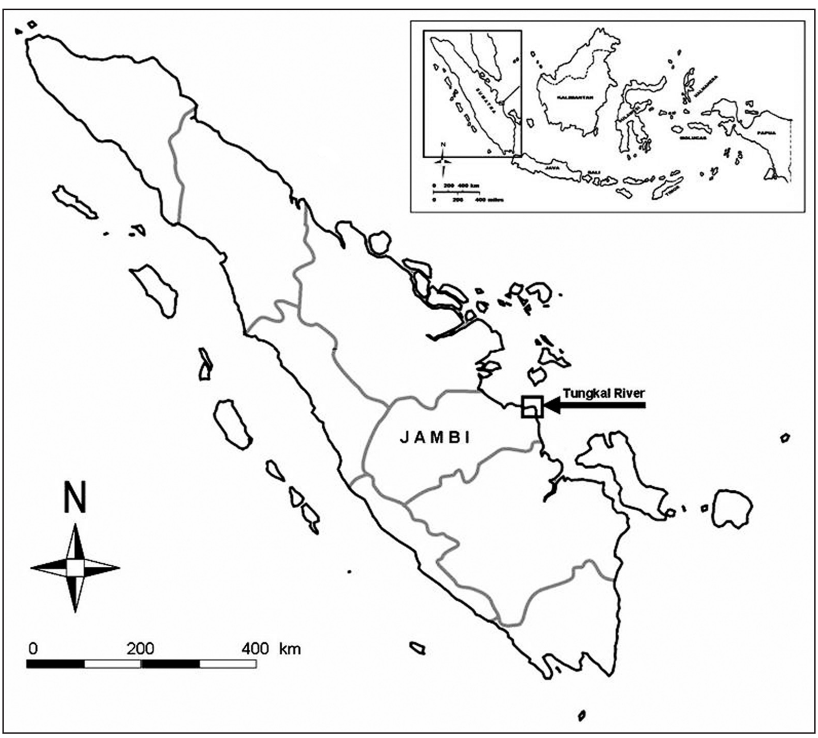

Figure 1. Research location. Black square indicates the mudflat where the shrimps were collected.

(one visible on the each of the sixth, seventh, and eighth thoracic segments, and (c) stage 3– gland development into three dense, thick lines that are connected medially (see Figure 5 in Wortham-Neal (2002)).

Body size (BL)-frequency distributions of total samples for both sexes was plotted using 2 cm intervals of Kubo's body length. The sex ratio of the entire population and each size classes were analysed using chi-squared tests with a correction called Yates' Correction for Continuity (Fowler & Cohen, 1992) to determine significant deviations from an expected 1:1 sex ratio.

Observation on gonad development of female in laboratory

To observe the gonad development of female shrimp, adult *Harpiosquilla raphidea* (body length more than 19 cm) were collected in November 2009 using a gill net. The collected mantis shrimps were dry-transported to the Laboratory of Aquatic Productivity and Environment, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Science, Bogor Agricultural University in an oxygenated container.

In the laboratory, the shrimps were placed into aquaria equipped with six artificial burrows made of PVC pipes for three females and three males (Figure 2). Ten replicates (30 females, 30 males) were used in the experiment. Some shrimps immediately entered the pipes, but some took time to use the pipes for their burrows. During observation, the shrimps were fed peeled penaeid shrimp. Long observation showed that most shrimp treated the pipe like a natural burrow (i.e., stayed in it, returned food to it, and cleaned it of excess food), and no cannibalism occurred if the food was enough. Females were monitored every day, and the presence of late-stage cement-gland development and ovaries that fuse in the telson, forming a "triangle" on the ventral surface was recorded (Deecaraman & Subramoniam, 1980, 1983; Stage 2 and 3 of gonad development in accordance to Wortham-Neal, 2002).

Figure 2. Aquarium arrayed in artificial burrows for the observation of gonad development of female *Harpiosquilla raphidea*.

RESULTS

Sex ratio of *Harpiosquilla raphidea* population

In the present study, the total collected shrimp was 375 specimens which consists of 223 females and 152 males, giving a female-biased sex ratio for the entire population [(1.47: 1), $\chi 2 = 13.45$, $p < 0.05$, $\chi 2$ test with Yates' correction; see Fowler & Cohen (1992)]. In terms of size, the collected shrimps ranged from 19.5 – 30.0 cm BL. Considering the size classes, it was noted that, in spite of the variability in the sex ratio values, the number of males and females belonging to each size was not statistically different until 25 cm BL (Table 1).

Size frequency distribution of *Harpiosquilla raphidea* population

The body size (BL)-frequency distributions of males and females collected on 15–20 November 2009 is presented in Figure 3. Both males and females show a symmetrical distribution, but the average size of females (24.38 cm BL) was significantly larger than that of males (23.92 cm BL) ($p < 0.05$; t-test for comparing the means as in Fowler & Cohen, 1992). The largest female (30.0 cm BL) was also larger than the largest male (28.7 cm BL).

Reproductive biology of *Harpiosquilla raphidea*

Reproduction aspect of shrimp is viewed from the gonad maturity. The gonad maturity is divided into three stages following Wortham-Neal (2002). The number of females with different stages of gonad maturity is presented in Figure 4. Females with Stage 1 dominated in most cases. Observations on the gonad development in the laboratory showed that in two weeks, three females showed gonad stage 2, and only 2 females developed their gonad into stage 3.

DISCUSSSION

The target species of the present study is *Harpiosquilla raphidea*, one of the two common mantis shrimps of the same genus inhabiting mudflats at the mouth of the Tungkal River, Jambi Province. The other species living in the research location is *Harpiosquilla harpax*.

Table 1. Number of specimens for both sexes at each size class and the results of χ^2 test.

Size class (cm)	No. of Males	No. of Females	Male/Female Ratio	χ^2 test	
19 – 21	3	3	1.00	0.17	ns at $p = 0.05$
21 – 23	33	39	0.85	0.51	ns at $p = 0.05$
23 – 25	42	57	0.74	0.28	ns at $p = 0.05$
25 – 27	47	69	0.68	4.18	*, $p < 0.05$
27 – 29	26	50	0.52	7.59	*, $p < 0.05$
29 – 31	1	5	0.20	2.83	ns at $p = 0.05$
Total	152	223	0.68	13.45	*, $p < 0.05$

Note: χ^2 test with Yates' Correction for Continuity (Fowler & Cohen, 1992)

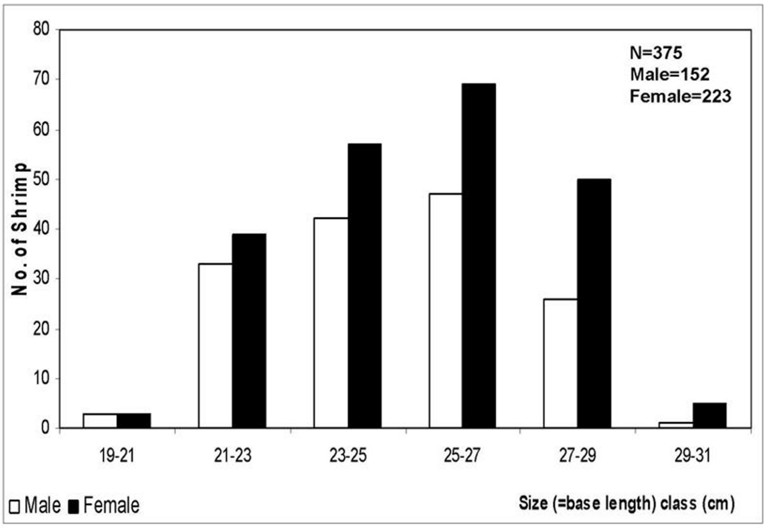

Figure 3. Body size (BL)-frequency distributions of male and female *Harpiosquilla raphidea* collected between 15–20 November 2009 in Tungkal River, Province Jambi, Indonesia.

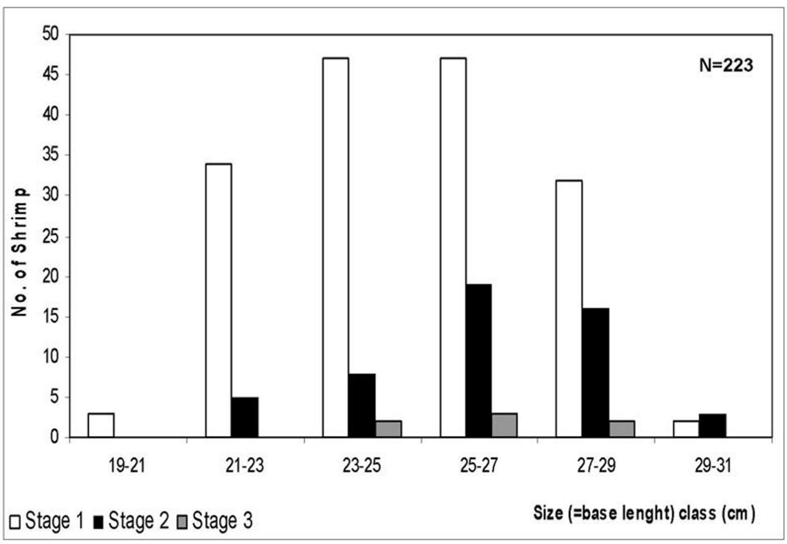

Figure 4. Number of females *Harpiosquilla raphidea* at different size classes with different stage of maturity.

Studies on biological or ecological aspects of mantis shrimp have been conducted for several species, such as *Oratosquilla oratoria* (Hamano & Matsuura, 1984; Hamano *et al*., 1987; Kodama *et al*., 2004, 2005, 2006a, 2006b; Ohtomi *et al*., 2005; Narita *et al*., 2007; Lui *et al*., 2009), *Pseudosquilla ciliate* (Kinzie, 1968), *Gonodactylus falcatus* (Kinzie, 1968), *Oratosquilla interrupta* (Yousuf, 2003), *Squilla empusa* (Wortham-Neal, 2002), *Haptosquilla pulchella* (Barber *et al*., 2002), *Hemisquilla californiensis* (Shelton, 2008), *Gonodactylus oerstedii* (Cronin & King, 1989), and *Gonodactylaceus mutates* (Cronin *et al*., 2000). Only few, if any, research has discussed sex ratio among mantis shrimps. Like most decapods crustaceans, the sex ratio for the entire population of *Harpiosquilla raphidea* was female-biased. However, variations in the ratios by size classes were detected. Unusual male-biased ratios for the whole population was found in some callianassid shrimp, such as *Callianassa kraussi* (Forbes, 1973), *C. subterranea* (Rowden & Jones, 1994) and *C. tyrrhena* (Dworschak, 1998). In callianassid shrimp population, records of female-biased sex ratio as an artifact of collecting methods were hypothesized by Rowden & Jones (1994). However, Pezzuto (1998) in his review wrote that female-biased patterns have been found in species living in various environments, and have been sampled with various gears/ methods, so it has nothing to do with sampling gears or methods.

In the present study, females dominated the larger size. This would probably be related to the behaviour of the males. After becoming mature, the males have to fight for mating partners. So, the number of males after maturation decreases gradually, yielding female-biased ratios in some larger classes. Combatant behaviour has been proven to cause serious injuries or even death of one or both opponents in *Neaxius vivesi* (Berrill, 1975). Such behaviour also characterized in some callianassid shrimps, such as *Callianassa filholi* (Devine, 1966), *Trypaea australiensis* (Hailstone, 1962), *C. tyrrhena* (Ott *et al*., 1976: as *C. stebbingi*), *C. subterranea* (Rowden & Jones, 1994), *Lepidophthalmus louisianensis* (Felder & Lovett, 1989), *Neotrypaea californiensis* (Bird, 1982), *Sergio mirim* (Pezutto, 1998) and *Nihonotrypaea harmandi* (as *Callianassa japonica*) (Tamaki *et al*., 1997). However, a reduced number of sexually mature males through fights and/or due to predation when they leave the burrow to rummage around for females, could have compensation for the decapods population: (1) as natural selection to get the 'best' specimens, (2) enhancing the probability of each surviving males to discover females by excavating randomly in every direction, and (3) as an alternative strategy to overcome the problem of locating mating partners below the sediment surface, without selecting strategies often used by other benthic animals (Pezzuto, 1998).

The topic of reproductive biology of mantis shrimp has received increasing amount of attention in these two decades. Hamano & Matsuura (1984) conducted a laboratory experiment to observe the behaviour of *Oratosquilla oratoria* when it laid eggs and guarded the mass eggs. Their experiment showed that the shrimp never laid eggs out of the artificial burrow. Christy & Salmon (1991) reviewed and compared the reproductive behaviour in mantis shrimps and fiddler crabs. Wortham-Neal (2002) conducted a study on reproductive morphology and biology of male and female *Squilla empusa*. In her study, she concluded that variation in reproductive morphology may influence selection pressures on mating behaviours in mantis shrimp. Male *Squilla empusa* may not advantage by protecting females because of the long and apparently unpredictable inter-molt period and production of consecutive broods of eggs. Wickler & Seibt (1981) suggested that for the shrimp, the best way for optimal reproductive achievement from the male's perspective may be pure-search. This pure-search tactic envisages that males should mate with all behaviourally receptive females. The male may then have a chance to pass on sperm-plug material along with sperm to females. This tactic of males may diminish the cost of postcopulatory mate-guarding of females. Males may then go away from this female to rummage around for the next available female since males can mate with more than one female. Kodama *et al*. (2004, 2006a) conducted a research on the reproductive aspect of *Oratosquilla oratoria* which was used for fisheries management of the shrimp. The important point of their study is that fisheries regulation during the spawning season is required to enhance the resilience of the stock size of *O. oratoria.* In particular, regulation around the spawning peak in spring, during which most large female shrimps with high fecundity spawn, might be effective for recovering larval abundance.

In the present study, the occurrence of various stages of gonad development in female shrimps may indicate simultaneous breeding. This phenomenon was also found in callianassid shrimp, *Nihonotrypaea japonica* (Wardiatno, 2002). Stage 3 of gonad maturity occurred in larger females *Harpiosquilla raphidea*. This could probably mean that egg deposition was initiated by larger-sized females at the beginning of the breeding season, while participation in reproduction by the smaller-sized females comes later. However, this hypothesis should be proven by studying the dynamic population of the shrimp.

The laboratory observation showed that non-reproductive females *Harpiosquilla raphidea* collected from the field mostly need about two weeks to develop their gonad to the stage 2. Only a few showed a gonad development from the stage 2 to stage 3 within two weeks after the date of collection from the field, which was indicated by the isosceles triangle ovarian shape on the ventral side of telson**.** For female *Oratosquilla oratoria,* such condition would be followed by spawning within a week (Hamano & Matsuura, 1984).

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