Zoological Studies **51**(6): 768-782 (2012)

Zoological Studies

Population Structure and Reproduction of the Mysid Shrimp *Acanthomysis thailandica* (Crustacea: Mysidae) in a Tropical Mangrove Estuary, Malaysia

Tueanta Ramarn[1,3], Ving-Ching Chong[1,2,*], and Yukio Hanamura[4]

[1]*Institute of Biological Sciences, University of Malaya, Kuala Lumpur 50603, Malaysia*
[2]*Institute of Ocean and Earth Science,University of Malaya, Kuala Lumpur 50603, Malaysia*
[3]*Department of Biology, Faculty of Science, Thaksin University, Phattalung Campus, Phattalung 93110, Thailand*
[4]*Japan International Research Center for Agricultural Sciences, Owashi 1-1, Tsukuba 350-8686, Japan*

(Accepted March 12, 2012)

Tueanta Ramarn, Ving-Ching Chong, and Yukio Hanamura (2012) Population structure and reproduction of the mysid shrimp *Acanthomysis thailandica* (Crustacea: Mysidae) in a tropical mangrove estuary, Malaysia. *Zoological Studies* **51**(6): 768-782. The mysid shrimp *Acanthomysis thailandica* Murano, 1988 in the Matang mangrove estuary showed large spatial and temporal variations in population density. Large numbers occurred on the mudflat where the mean salinity was 25 ppt, but rapidly declined towards the upper estuary (14 km upstream) where the salinity fell to 15 ppt. Mysids were present year-round and exhibited marked monthly variations in abundance, with modal peaks in May, Sept., and Dec. 2009 and Apr. 2010 in the mudflat area. All developmental stages were observed, except juveniles which were absent from the middle to upper estuary. Females predominated over males and matured at a smaller size. Juveniles and empty (= post-spawning) females comprised the largest groups (at about 17% for each stage) of the population on the mudflat suggesting that the mudflat serves as the main spawning and nursery ground. Brooding females occurred together with juveniles in all monthly samples, indicating that reproduction was year round. Brood size was independent of female body length, and ranged 5-25 embryos per brood. Mean lengths of eggs (0.26 ± 0.03 mm), and eyeless (0.58 ± 0.06 mm) and eyed larvae (0.73 ± 0.10 mm) were also independent of total length.
http://zoolstud.sinica.edu.tw/Journals/51.6/768.pdf

Key words: Reproductive biology, Spatial and temporal abundance, Developmental stages, Mudflat area, Crustacea.

Mysid shrimps (Crustacea: Mysidae) are major organisms in many estuarine and coastal ecosystems (Azeiteiro and Marques 1999, Munilla and Vicente 2005). They occur in high numbers, and their ecological importance, particularly their role in food chains, is becoming increasingly apparent (Roast et al. 1998, Drake et al. 2002). Mysids play important roles in the trophodynamics of coastal ecosystems (Fanelli et al. 2009), feeding on detritus, phytoplankton, and zooplankton (Kouassi et al. 2006). In turn, they serve as prey food for other marine organisms (Beyst et al. 2001), thus providing a trophic link between primary producers and secondary consumers.

Both field and laboratory studies on mysids are widespread throughout the world especially in temperate regions (Mauchline 1973, Jones et al. 1989, Pothoven et al. 2000, Baldó et al. 2001, Scharf and Koschel 2004, Mendonça et al. 2009, Rappé et al. 2011). In contrast, biological and ecological data pertaining to tropical mysids are scanty. This is unfortunate because mysid populations in some tropical habitats can be very significant (Hanamura et al. 2007 2009).

*To whom correspondence and reprint requests should be addressed. Tel: 603-79674220. Fax: 603-79674178. Present address: National Research Institute of Fisheries Science, Fisheries Research Agency, Fuku-ura-2-12-4, Kanazawa-ku, Yokohama 236-8648, Japan. E-mail:chong@um.edu.my

Moreover, life-history traits of mysids can differ over geographical areas, while temperature is known to affect their ecophysiology (Mauchline 1980, Wittmann 1984). Hence, comparative studies between temperate and tropical mysids pertaining to their biology and behavior are needed to further understand the ecological role of these small hyperbenthic crustaceans.

Acanthomysis thailandica Murano, 1988 is the most abundant mysid species in the Matang Mangrove Forest Reserve (MMFR), Malaysia, forming large aggregations especially on a coastal mudflat where they comprised 70% of the total mysid population (this study). In spite of their high abundance in the Matang mangrove ecosystem, mysid shrimps are poorly studied, unlike penaeid shrimps which are the most researched crustacean of interest in mangroves (Ronnback et al. 2002, Faunce and Serafy 2006, Chong 2007). This is because of their small size, non-obvious economic value, and difficulty in identification. However, in the Matang mangroves, mysid shrimps are consumed by juvenile clupeid, sciaenid, mullid and gobiid fishes that use the mangrove as a feeding ground (Chew et al. 2007).

Published works on Malaysian mysid shrimps are markedly lacking. Hanamura et al. (2007) reported on the abundance and distribution of mangrove hyperbenthic crustaceans which included mysid shrimps. Hanamura et al. (2008b) further described the reproductive biology of the mysid species, *Mesopodopsis orientalis* (Tattersal, 1908) (now *M. tenuipes* Hanamura, Koizumi & Sawamoto 2008) (Hanamura et al. 2008a) in a Malaysian mangrove estuary. With the exception of some descriptions by Hanamura et al. (2007 2008a b), there is no single study on *A. thailandica* in Malaysian waters. Therefore, given the dense populations of mysid shrimps in a mangrove habitat that is well known for its feeding and nursery ground function (Sasekumar et al. 1994, Ahmad Adnan et al. 2002, Chong 2007) and which supports the largest fisheries in the country, the aim of the present study was to elucidate the population structure and reproductive habits of this neglected shrimp species.

MATERIALS AND METHODS

Sample collection

Sampling locations for mysid shrimp were located in the MMFR and an adjacent coastal mudflat. Four sampling stations were established from station S1, located on the coastal mudflat, through stations S2 (4.4 km upstream), S3 (9.6 km), and S4 (14.1 km) in the main channel of Sangga Besar River (Fig. 1). Mean water depths at these stations were 1.02 ± 0.39 (mean ± S.E.), 1.34 ± 0.93, 2.1 ± 1.29, and 2.42 ± 1.16 m, respectively. Mysid shrimp were sampled monthly from Oct. 2008 to June 2010 (except in Nov. 2008), during low tides using a mud sledge (Pullen et al. 1968). The sledge net had a 0.53 × 0.16-m mouth area and a 2.35-m-long net of 500-μm mesh size. It was pulled over the mud bottom by first paying out a fixed 30-m length of a tow line from a moving boat, stopping the boat, and then pulling in the net by hand onto the deck. The boat was 8-m long with a low freeboard. The collected sample was completely emptied into a pail before large mangrove leaves and debris were removed, and the entire contents were then washed into a 1-L sample bottle containing a borax-buffered 4% seawater-formalin solution (Grabe et al. 2004).

Two more replicate samples following the same sampling procedure were also taken. In addition, environmental data such as salinity, temperature, pH, and dissolved oxygen (DO) were measured just above the mud bottom with a Hydrolab 4e sonde (Hach Hydromet, Loveland, Colorado, USA). All monthly samplings were carried out during the daytime when hyperbenthic animals are known to be concentrated near the bottom (Verslycke and Janssen 2002).

Laboratory analysis

In the laboratory, *A. thailandica* and other mysid shrimps were sorted out and counted under a stereomicroscope. The total length (TL, mm) was measured from the anterior margin of the rostrum to the posterior end of the telson, excluding the setae, with an ocular micrometer mounted on a stereomicroscope. Individuals were sexed and classified into one of 7 developmental stages based on the appearance of their sexual characteristics, namely, (1) juvenile (absence of sexual characteristics); (2) immature or sub-adult male (penes on the 8th thoracic limb rudimentary, 4th pleopod extended, and process masculinus present, but with no or few setae); (3) mature male (penes and secondary sexual characteristics completely developed), (4) immature or subadult female (rudimentary empty marsupium present); (5) mature female (marsupium fully developed, with no eggs or larvae); (6) brooding or ovigerous female (marsupium with eggs or larvae); and (7) empty female (developed marsupium void of contents) (Mauchline 1980, Delgado et al. 1997). All examinations and measurements were made from more than 200 specimens, if available.

The brood size and brood stage of females with unruptured marsupium were recorded each month. The brood stage was classified according to Mauchline (1980), which is based on the development of the marsupium contents (egg or embryo) as follows: stage 1 (egg), round egg containing developing embryo; stage 2 (eyeless larva), hatched larva with observable antennae and thoracic appendages; and stage 3 (eyed larva), molted larva with pigmented and stalked eyes. Larval size was measured as the diameter of the egg stage, whereas the length from the frontal to the terminal tip of the body was measured for both eyeless and eyed larval stages.

Data analysis

Analysis of variance (ANOVA) and post-hoc Tukey's honestly significant difference (HSD) test were conducted to compare mysid shrimp abundances, water parameters, proportion of brooding females carrying eggs, eyeless and eyed larvae, body length of brooding females, and brood

Fig. 1. Map showing the sampling area and stations in the Matang mangrove estuary, Peninsular Malaysia.

size (numbers of eggs, eyeless larvae, and eyed larvae) among sampling stations. All datasets were first tested for normality and homoscedascity, failing which the data were logarithmically transformed [log(x+1)] or arcsine-transformed (for proportions) as required for the parametric analysis (Sokal and Rohlf 1998).

Spearman's rank correlation test was used to determine correlations of abiotic factors with mysid shrimp abundances, of female total length with brood size, and of female total length with egg/larval length. Levels of significance were tested at $p = 0.05$. All statistical analyses were performed using the Statistica vers. 9 Software Package (StatSoft, Tulsa, Oklahama, USA). All mean data presented in the text and figures include the standard error (± S.E.).

RESULTS

Water parameters

Recorded water parameters from Oct. 2008 to June 2010 are presented in figure 2, with the exception of Apr. 2009 when the instrument malfunctioned. Water temperatures were rather stable throughout the study period, ranging 26.47-31.09°C. On the other hand, salinity showed a clear horizontal gradient along sampling sites, with the highest mean annual salinity (24.49 ± 0.50 ppt) recorded at the mudflat (S1) and the lowest salinity (15.07 ± 0.07 ppt) recorded at the upper reach of the estuary (S4). DO showed great temporal variations throughout the study period, ranging 1.12-5.49 mg/L. Mean water pH was near neutral, but ranged 6.16-7.94.

Acanthomysis thailandica population

Abundance

Mean densities of *A. thailandica* significantly differed (ANOVA $F_{1,79} = 3.38$, $p < 0.05$) among sampling stations with the highest density (139.57 ± 30.42 ind./m^2) occurring on the mudflat (S1). From the mudflat, the mean density dramatically decreased in an upstream direction, through the river mouth (33.81 ± 10.86 ind./m^2 at S2), the middle reach (2.56 ± 1.87 ind./m^2 at S3) to the upper reach (0.19 ± 0.08 ind./m^2 at S4). However, mean mysid densities among the latter 3 stations did not significantly differ (by post-hoc Tukey's HSD test) from each other.

Monthly densities of *A. thailandica* in the Matang mangrove showed marked temporal fluctuations at all sampling stations. Modal density peaks, reflecting the temporal pattern of mysid recruitment in the mudflat, were observed in May, Sept., and Dec. 2009 and Apr. 2010 (Fig. 3A). At the river mouth area, modes in Sept. 2009 and Jan. 2010 coincided with or were close to those observed on the mudflat (Fig. 3B). However, the July 2009 mode was observed in the middle and upper reaches of the estuary, but not at the mudflat (Fig. 3C-D). Only in the former 2 areas were other modes observed in Oct. 2008 and Feb. 2009.

Developmental stages and size

Figure 4A-E show the various developmental stages of male and female *A. thailandica*. The smallest captured juvenile of indeterminate sex was 1.68 mm which first developed into an immature male or female at approximately the same size. Immature and mature shrimp of both sexes showed a wide range in size where, within the same developmental stage, the largest individual could have a total length twice that of the smallest individual (Table 1).

Sex ratio

The sex ratio varied among sampling stations and months, with ranges of 0.70-3.5, 0.62-3.67, 1.00-3.86, and 1.17-2.5 at the mudflat, river mouth, middle reach and upper reach, respectively.

Population structure

The mysid population at the mudflat and river mouth comprised all developmental stages from the youngest juveniles to the oldest, empty females, but their abundances differed. The population at the middle and upper reaches had quite similar structures, but their numbers were highly variable, both spatially and temporally.

At the mudflat, juveniles and empty females generally formed larger groups (17.08% ± 2.63% and 17.02% ± 2.04% of the population, respectively), while mature females formed the smallest group (5.36% ± 0.85% of the population). Immature males, immature females, and mature males contributed about equally to the population size (15.37% ± 1.32%, 16.38% ± 1.85%, and 16.96% ± 2.00%, respectively), while brooding females contributed 9.31% ± 1.76%. The largest juvenile group (56.40% of the population) was

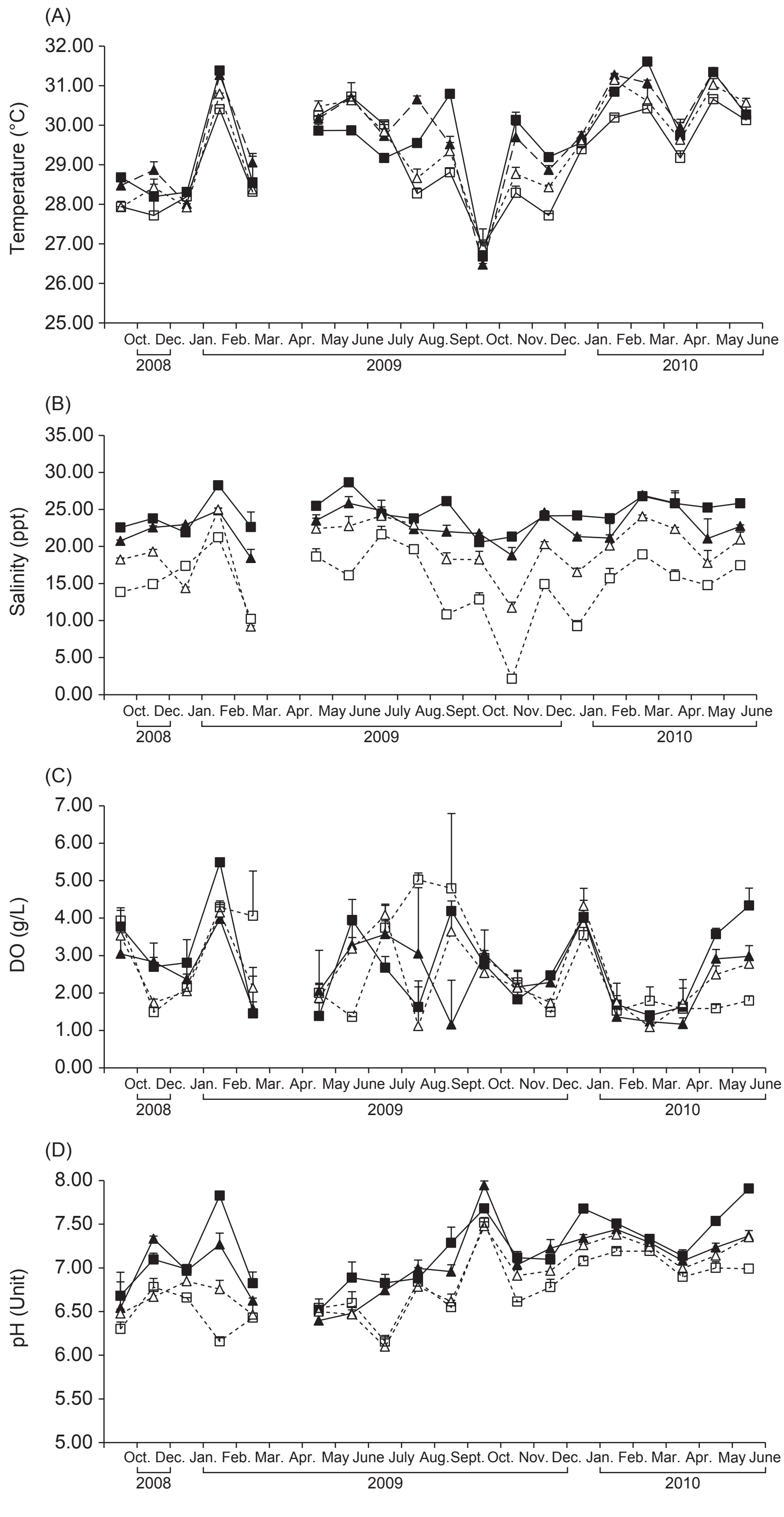

Fig. 2. Monthly variations in water parameters (mean ± S.E., *n* = 3) of (A) temperature, (B) salinity, (C) dissolved oxygen (DO), and (D) pH at the Matang mangrove estuary during Oct. 2008-June 2010. Data were not available in Apr. 2009 because of equipment malfunction. Closed square, station 1; closed triangle, station 2; open triangle, station 3; open square, station 4.

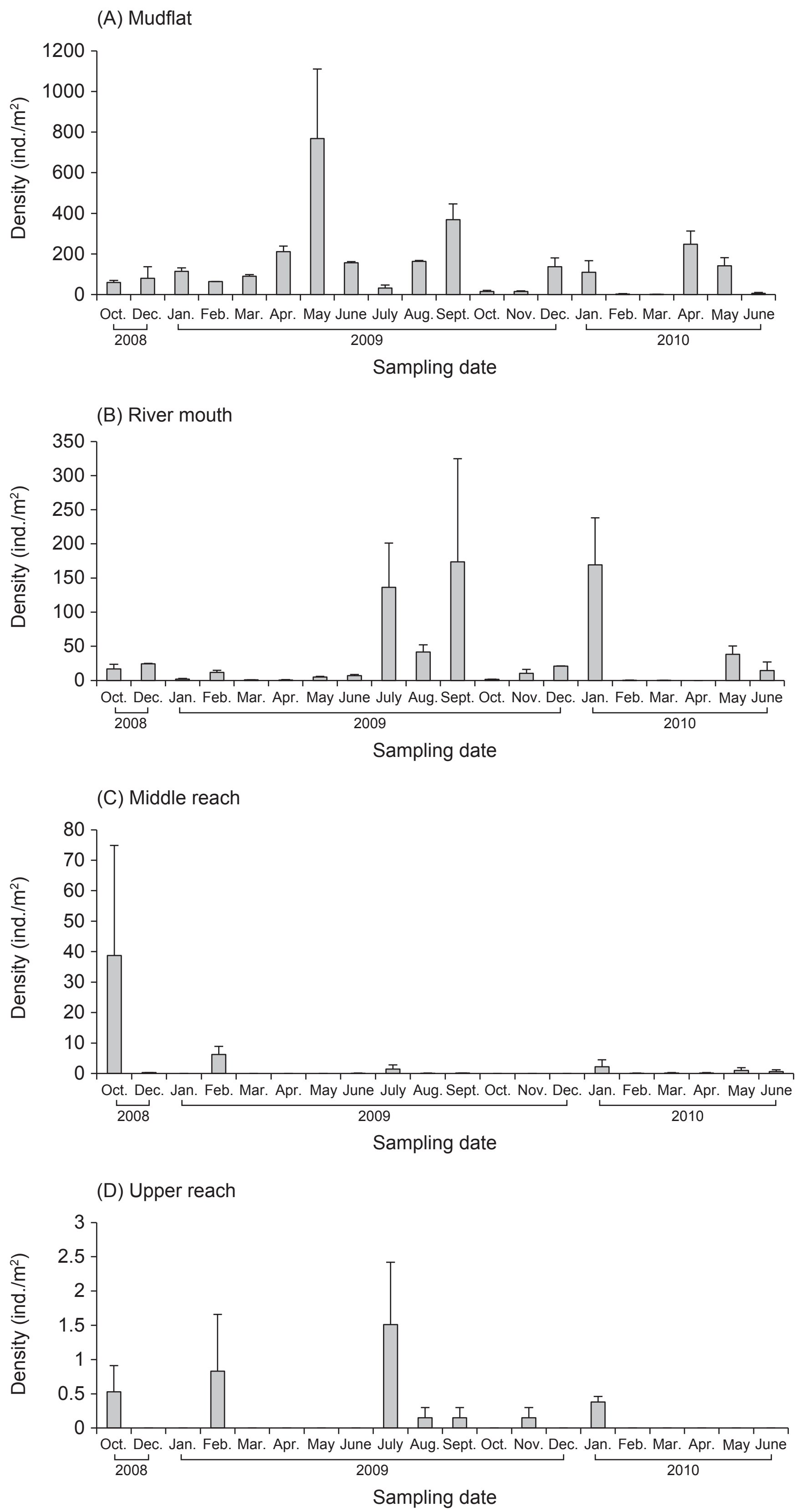

Fig. 3. Monthly mean density (± S.E., n = 3) of the mysid shrimp *A. thailandica* at each sampling station of the (A) mudflat, (B) river mouth, (C) middle reach, (D) upper reach, in the Matang mangrove estuary, Oct. 2008-June 2010 (Nov. 2008 not sampled).

observed in Apr. 2009, while smaller ones were subsequently observed in Aug. and Sept. 2009, Jan. and Feb. 2010, and Apr. 2010 (Fig. 5A). Immature males and females together comprised 29% of the population, while adults or mature males and females formed < 15%. The adult group however dominated (70% of population) in June 2009, but had sharply declined by Aug. 2009. Like juveniles, empty females were found every month, but the highest numbers occurred in Mar., June, Sept., and Nov. 2009 (Fig. 5A) suggesting major spawning months.

The mysid population structure at the river mouth closely resembled that at the mudflat. Empty females formed the largest group (22.42% ± 3.64%), whereas mature females formed the smallest group (5.44% ± 1.37%). On the other hand, mature males were the 2nd largest group (17.71% ± 2.76%), while immature females, brooding females, juveniles, and immature males were about equal in their proportions (13.62% ± 7.68%, 12.50% ± 3.06%, 11.74% ± 3.62%, and 11.01% ± 1.78% of the population, respectively). The largest group of juveniles was observed in Apr. 2009 (62.50%), and smaller ones were observed in Aug., Oct. to Nov. 2009 and Feb. 2010 (Fig. 5B). Empty females were observed every month except Apr. 2009 and Mar. 2010, but mainly in Mar., June,

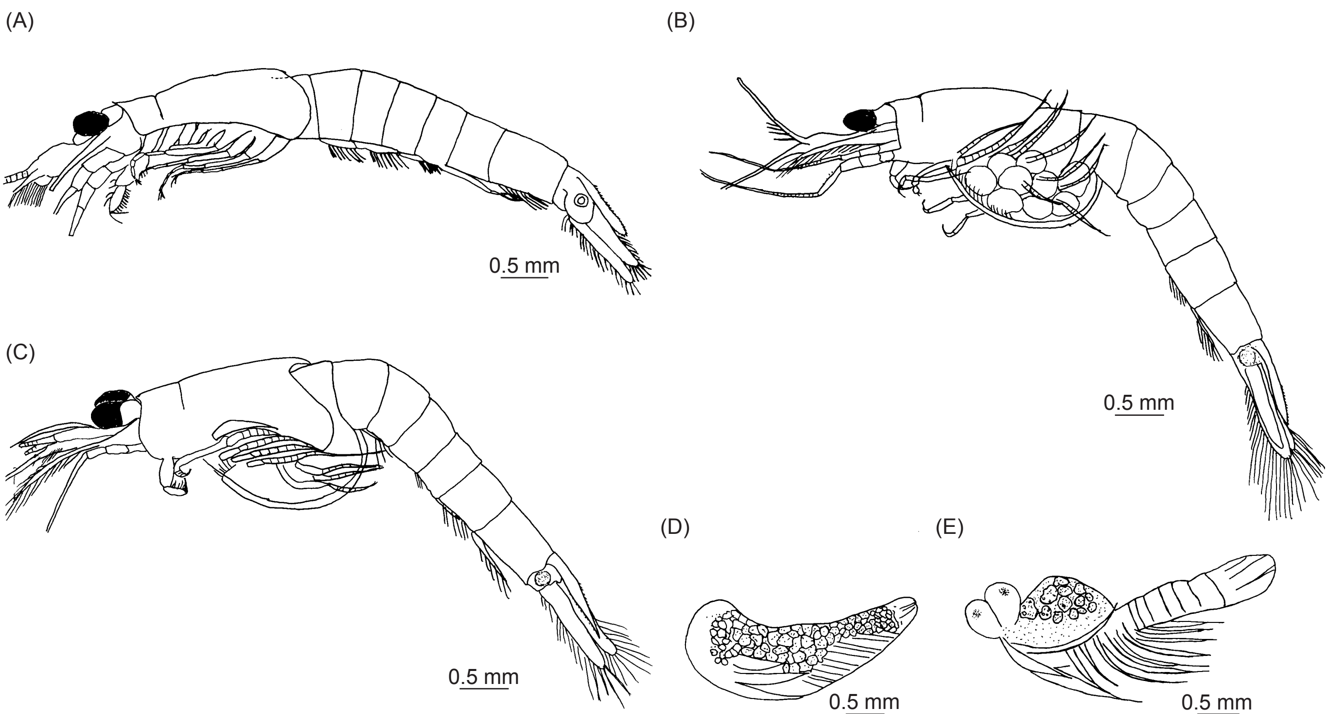

Fig. 4. Mysid shrimp *A. thailandica* (A) mature male, (B) brooding female, (C) empty female, (D) eyeless larva, and (E) eyed larva.

Table 1. Total length (mm) of the mysid shrimp *A. thailandica* in the Matang mangrove estuary, Malaysia, during Oct. 2008-June 2010 (Nov. 2008 not sampled)

Stage	Mean ± S.E.	Minimum	Maximum	*n*
Juvenile	2.55 ± 0.01	1.68	1.68	752
Immature male	3.55 ± 0.02	2.25	2.25	869
Mature male	4.69 ± 0.02	3.25	3.25	907
Immature female	3.40 ± 0.02	2.25	2.25	806
Mature female	4.07 ± 0.02	2.55	5.28	457
Brooding female	4.66 ± 0.01	3.05	3.05	656
Empty female	4.74 ± 0.01	3.36	3.36	782

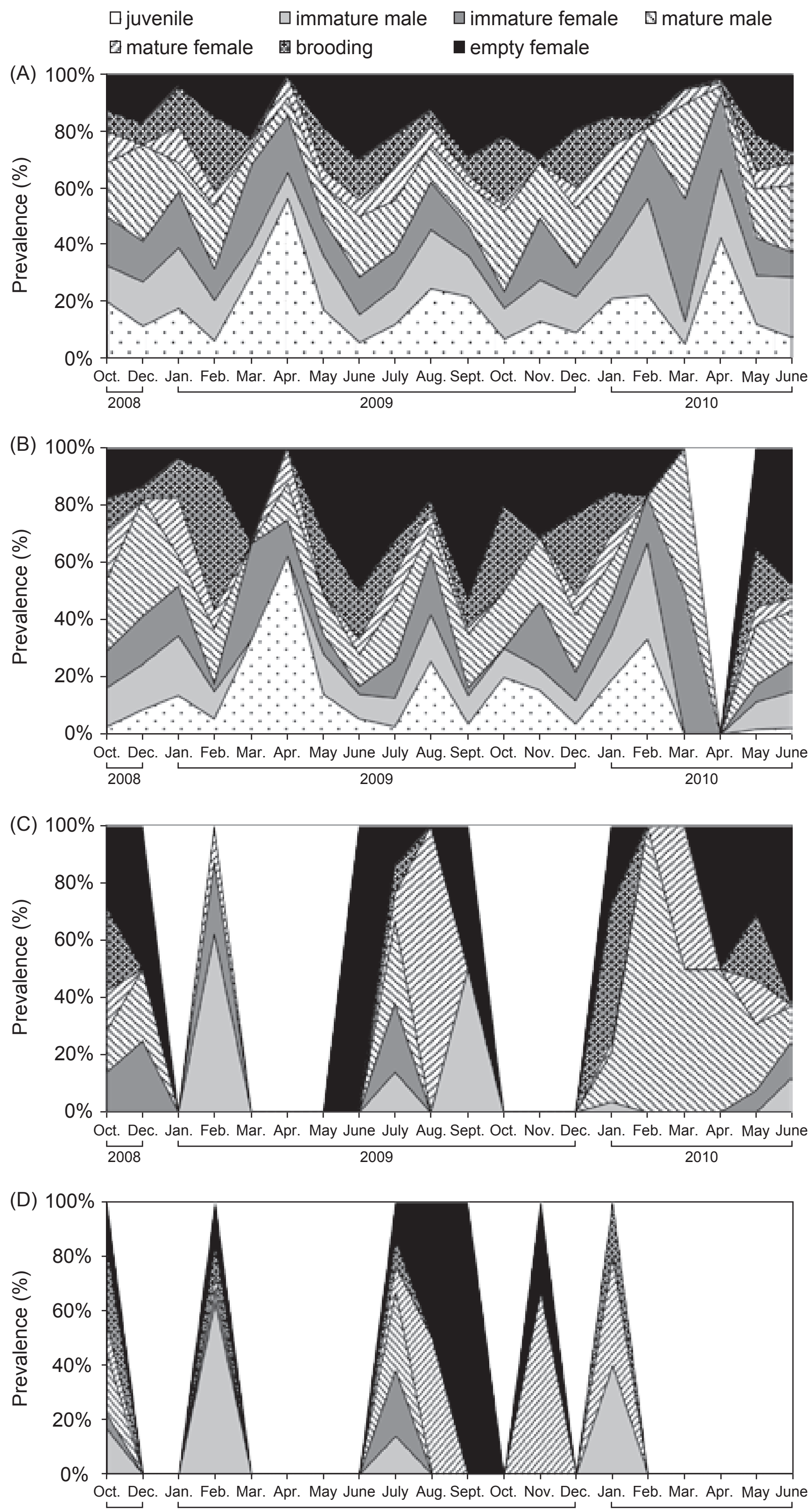

Fig. 5. Population structure of the mysid shrimp *A. thailandica* sampled at (A) the mudflat (S1), (B) river mouth (S2), (C) middle reach (S3), and (D) upper reach (S4) in the Matang mangrove estuary, Oct. 2008-June 2010 (Nov. 2008 not sampled).

Sept., and Nov. 2009. No mysid shrimp were collected in Apr. 2010 at the river mouth.

No juveniles were collected in the middle or upper reach (Fig. 5C, D). At these stations, the combined mature stages (including brooding and empty females) outnumbered the immature stages; the mature stages represented 64.45% of the population, while immature stages formed 35.55% (Fig. 5C, D). Empty females formed the largest group at the middle (31.85% ± 8.38%) and upper reaches (32.87% ± 12.71%). In contrast to the mudflat and river mouth, mysid shrimp were not regularly present in the middle and upper reaches, being completely absent in 7 (35%) and 13 (65%) mo of the 20 mo of sampling, respectively.

Reproduction

Brooding females and brood size

Brooding females were observed throughout the study period, except in Apr. 2009. There were significant differences (ANOVA $F_{1,59}$ = 20.65, $p < 0.05$) among the proportions of brooding females (F1, F2, and F3) carrying embryos of different developmental stages. F3 females (carrying eyed larvae) comprised only 10.02% ± 2.68% of the total brooding females, and were significantly (HSD, $p < 0.05$) the smallest group compared to F1 females (carrying eggs) and F2 females (carrying eyeless larvae), which respectively comprised 40.69% ± 4.80% and 44.69% ± 4.63% (HSD, $p > 0.05$) of the brooding population.

The data suggest that the brooding female instar continues to lengthen while the eggs develop through eyeless and eyed larvae inside the marsupium. Mean body lengths of brooding females were 4.62 ± 0.34 mm for F1, 4.75 ± 0.30 mm for F2, and 4.83 ± 0.36 mm for F3, which significantly differed (n = 366, F = 10.51, $p < 0.01$).

Monthly brood sizes were variable (Table 2) and significantly differed among the 3 brooding stages (ANOVA, $F_{1,365}$ = 4.83, $p < 0.01$). However, no significant difference (post-hoc Tukey's HSD, $p > 0.05$) was observed between brood sizes of F1 and F3 females, which had mean brood sizes of 10.35 ± 0.36 and 10.38 ± 0.56 ind./brood, respectively. The mean brood size for F2 females was 9.09 ± 0.25 ind./brood. In addition, the brood size of all brooding stages was not significantly correlated (Spearman's rank correlation test, $p > 0.05$) with female total length (Fig. 6); r_s = 0.27 (n = 141) for F1; r_s = 0.26 (n = 175) for F2, and r_s = 0.21 (n = 50) for F3. Thus, brood size did not increase with increasing female length (Fig. 6A-C).

Table 2. Brood size of *A. thailandica* in the Matang mangrove estuary from Oct. 2008 to June 2010 (Nov. 2008 not sampled). Data show only the month when brooding females were present. Numbers within brackets indicate the standard error

Month	Eggs			Eyeless larvae			Eyed larvae		
	Mean	Range	*n*	Mean	Range	*n*	Mean	Range	*n*
Oct. 2008	9.00 (1.31)	5-14	7	7.75 (0.56)	6-10	8	10.83 (0.93)	6-17	12
Dec.	6.80 (0.70)	5-11	10	8.22 (0.44)	5-12	7	-		
Jan. 2009	11.83 (1.25)	6-19	12	-			-		
Feb.	11.58 (0.94)	5-18	19	8.00 (0.84)	5-11	7	12.00 (1.00)	1-13	2
Mar.	6.00 (0.00)	6	1	10.00 (0.00)	10	1	-		
May	9.08 (1.45)	5-19	12	8.43 (1.21)	5-13	7	19.00 (0.00)	19	1
June	12.52 (1.14)	5-25	23	11.53 (1.01)	6-20	17	15.00 (3.21)	10-21	3
July	8.87 (1.27)	5-17	8	11.60 (1.13)	6-17	10	13.00 (3.00)	10-16	2
Aug.	11.85 (0.87)	7-19	13	11.42 (1.10)	7-18	12	9.67 (3.28)	5-16	3
Sept.	8.50 (1.55)	6-13	4	8.18 (1.01)	5-15	11	13.00 (1.73)	10-13	3
Oct.	8.00 (1.69)	5-16	6	9.50 (2.06)	5-19	6	-		
Dec.	10.00 (0.91)	6-17	17	9.07 (0.67)	5-20	27	8.37 (0.80)	6-13	8
Jan. 2010	9.87 (1.20)	5-22	15	9.65 (0.65)	5-16	20	10.83 (2.24)	5-19	6
Apr.	-			5.33 (0.33)	5-6	3	-		
May	-			7.58 (0.45)	5-15	31	8.15 (0.82)	5-15	13
June	-			7.00 (0.00)	7	1	-		
Mean	**10.35 (0.36)**	**5-25**	**147**	**9.09 (0.25)**	**5-20**	**179**	**10.38 (0.56)**	**5-21**	**53**

n = number examined.

Egg and larval lengths

Embryos within the same marsupium were at the same developmental stage, but could differ from other marsupia in the same mysid population. Egg and larval lengths fluctuated throughout the year (Fig. 7). Mean lengths of eggs, eyeless larvae, and eyed larvae were 0.26 ± 0.03, 0.58 ± 0.06, and 0.73 ± 0.10 mm, respectively. Lengths of eggs and larvae were not related ($p > 0.05$) to female total lengths. Spearman's rank correlations of female total length with egg length, eyeless larval length, and eyed larval length were $r_s = 0.02$ ($n = 1,735$), $r_s = 0.01$ ($n = 1867$), and $r_s = 0.12$ ($n = 583$), respectively; no correlations were significant ($p > 0.05$).

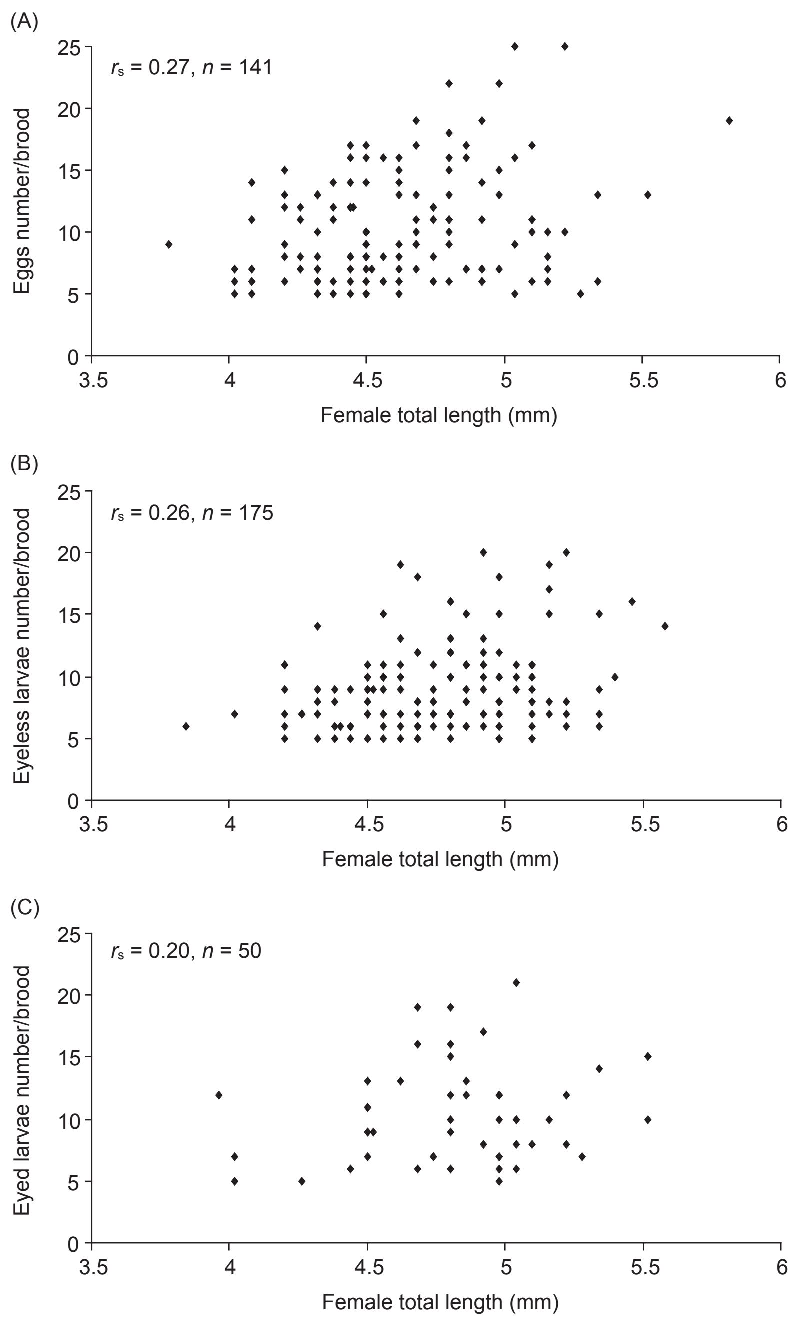

Fig. 6. Relationship between the total length of females and numbers of (A) eggs, (B) eyeless larvae, and (C) eyed larvae (pooled data from all stations). r = correlation coeffient; n = sample size.

DISCUSSION

Acanthomysis thailandica is an euryhaline species reported to also occur in the Merbok mangrove estuary of Malaysia (Hanamura et al. 2007, as *A. indica* Tattersall 1922) and the Gulf of Thailand (Murano 1988). In the Matang mangrove estuary, the species is common, but showed large spatial and temporal variations in population densities. Its highest mean density occurred on the mudflat, its preferred habitat. The Matang estuary however supports a much-larger population of mysid shrimps; *A. thailandica* together with 7 other mysid species had a mean total density of 405 ind./m^2.

Although the abundance of *A. thailandica* showed large monthly fluctuations in the Matang mangrove, modes of major recruiting populations were observed in May, Sept., and Dec. 2009 and Apr. 2010, indicating also annual variability. Based on rainfall data over a 12-yr period (1995-2006), Chew and Chong (2011) reported that the heaviest rainfall in the Matang area usually occurs in Oct.-Dec., prior to or during the onset of the northeasterly (NE) monsoon (Nov.-Mar.). Another less-wet period occurs in Apr. corresponding to the inter-monsoon month, a period of variable wind conditions just before the onset of the drier southwesterly (SW) monsoon season (May-Sept.). The present results thus indicate a possible connection between mysid abundance and rainfall or its effect on water parameters. Monsoonal effects on water conditions, productivity, and biota were reported in tropical waters by various workers (Pauly and Navaluna 1983, Nair et al. 1989, Jyothibabu et al. 2006). For instance, the population dynamics of *Mesopodopsis orientalis* and *M. zeylanica* Nouvel, 1954 were reported to be strongly correlated to the monsoon (George 1958, Biju and Panampunnayil 2010 2011), although a weak association with the monsoon was reported for *M. orientalis* in Hooghley estuary, India (Sarkar and Choudhury 1986).

Monthly water parameter measurements in the present study indicated maximum salinity dilutions from 21 to 2 ppt in the upper estuary and 29 to 21 ppt on the mudflat, from June/July (dry period) to Nov. 2009. There was also an apparent depression in surface water temperature during the NE monsoon (or winter monsoon), as well as DO concentration in the monsoon (Fig. 2). Depressed DO levels may be associated with higher turbidity levels due to increased riverine inputs (Chew and Chong 2011). Nevertheless, results from the correlation analysis showed that among the physical parameters, only salinity had a significant effect on the spatial distribution of *A. thailandica* in the Matang mangrove estuary (not reported in this paper), where the highest mysid density at the mudflat was observed to decrease towards the upper estuary. Juveniles of *A. thailandica* are probably less tolerant of low salinity compared to adults since they were absent in the upper estuary. Salinity effects on mysid distributions in other estuaries are well documented for other species (Baldó et al. 2001, Biju and Panampunnayil 2011, Hwang et al. 2010, Rappé et al. 2011). Yamada and Yamashita (1995) reported that the survival rate of juvenile *A. mitsukurii* Nakazawa, 1910 (now *Orientomysis mitsukurii*) was lower at salinities of < 20 ppt. On the other hand, Suzuki et al. (2009) attributed the

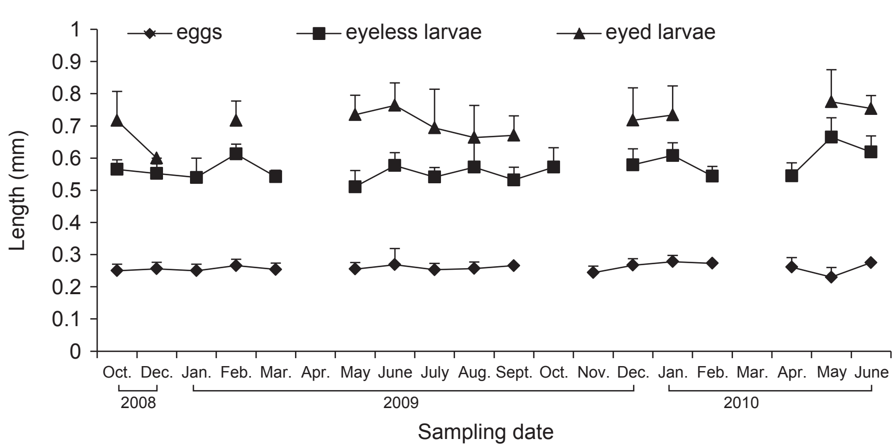

Fig. 7. Monthly variations (mean ± S.E.) of lengths of the eggs, eyeless larvae, and eyed larvae of the mysid shrimp *A. thailandica* in the Matang mangrove estuary, Oct. 2008-June 2010 (Nov. 2008 not sampled).

lower numbers of *Hyperacanthomysis longirostris* Ii, 1936 in the upper estuary of the Chikugo River (Japan) to prevailing tidal currents and circulation, appa-rently due to their weaker swimming ability.

According to Hanamura et al. (2009), food availability may determine mysid abundance. This may be more important in Matang's coastal mudflat where salinity changes are not extreme (as they fluctuate within a range of 8 ppt), while the temporal variability in mysid abundance appeared to be dramatic (Fig. 3). Mysids are known to feed on zooplankton species (Fockedey and Mees 1999, Kouassi et al. 2006, Vilas et al. 2008), and their primary food source at the mudflat and river mouth is likely phytoplankton and/or benthic diatoms, as revealed by stable carbon isotope studies (Tanaka et al. 2011). In Matang estuarine waters, copepod abundance was associated with salinity, chlorophyll *a*, and turbidity gradients that were influenced by the seasonal rainfall pattern (Chew and Chong 2011). They also reported the significantly higher abundance of copepods during the NE monsoon season, particularly during Oct.-Dec. In the present study; however, the size of the mysid population in Dec. was much smaller than that in May which was not a wet month. Therefore, mysid abundance cannot be ascribed to any single environmental factor. Similarly, Biju et al. (2009) reported that the population density of mysids in Cochin estuary (India) was influenced by several factors including temperature, chlorophyll *a* concentration, DO, and salinity.

Our results showed that the reproductive traits of *A. thailandica* were similar to those of *M. tenuipes* and *M. orientalis* that inhabit mainly mangroves and sandy beaches in Malaysia, respectively (Hanamura et al. 2008b 2009). *Mesopodopsis orientalis* showed no seasonal variation in its reproductive stages, indicating that spawning occurs year round, although several spawning peaks were observed. On the other hand, mysid shrimps from the Netherlands and Japan produce 3 distinct generations, over-wintering, summer, and spring generations, during a year (Toda et al. 1982, Mees et al. 1994). Temperate mysid populations reach their peak in spring-summer in accordance with the rise in water temperature.

The pattern of reproduction and number of generations appear to vary among species and between populations of mysids. In general, temperate mysids produce 2 or 3 generations annually (Mees et al. 1994, Viñas et al. 2005), whereas tropical mysids reproduce continuously (Goodbody 1965). This was substantiated by the present study for *A. thailandica*, as well as other tropical mysids such as *Mesopodopsis* (Hanamura et al. 2008b 2009, Biju et al. 2009, Biju and Panampunnayil 2011). However, unlike temperate mysids, it is difficult to trace the progression of cohorts of tropical mysids due to their rapid growth, early maturity, and short lifespan (Mauchline 1980, Sudo et al. 2011). Sudo et al. (2011) reported that the spawning and recruitment of *Orientomysis robusta* (Murano, 1984) occurred throughout the year, and 19 overlapping cohorts were recognized over an annual cycle. Their findings were based on weekly samplings combined with growth rate studies in the laboratory.

The body length of brooding females generally increases as embryos develop in the marsupium. However, females do not molt while carrying eggs or larvae in the marsupium. Thus, the increase in body size is believed to be the result of intermolt growth achieved through stretching of the abdominal joints (Mauchline 1973, Fenton 1994). However, Hanamura et al. (2009) suggested that such somatic growth of the abdomen might not explain the size increment in the breeding female population of *M. orientalis*, since the apparent growth could be due to the higher mortality of small females compared to larger females, thus contributing to the observed phenomenon.

Brood size is related to female body length in many temperate mysids, i.e., brood size increases with increasing female body length (Allen 1982, Mees et al. 1994, Hanamura et al. 2008b, Biju et al. 2009, Biju and Panampunnayil 2011). However, this relationship was not observed in *A. thailandica*. Also, females of the same length had different brood sizes. Similarly, *Mysidopsis californica* Tattersall, 1932 reared under semi-controlled conditions also showed a low correlation ($r = 0.27$, $p = 0.196$) between the number of released juveniles and female length (Ortega-Salas et al. 2008). The reason for this is not clear. In the present study, brood size bore no significant correlation ($p > 0.05$) with environmental factors such as salinity ($r_s = 0.24$) or temperature ($r_s = 0.04$). Mauchline (1980) noted that although numerous species exhibit a relationship between the number of young and female body length, it is difficult to demonstrate this in mysid species smaller than 10 mm in body length, because the number of young (brood size) carried by females of equal body length also varies.

Mean brood sizes of females carrying eggs and eyed larvae did not significantly differ in the present study. The present results also showed no loss of embryos, or if there was, it was negligible throughout development in the marsupium. This is in contrast to embryo loss reported in some mysid species (Mauchline 1980, Fenton 1994, Calil and Borzone 2008) which may result from cannibalism or parasitism (Wittmann 1984).

CONCLUSIONS

The Matang mangrove estuary is continuously utilized as habitat by dense populations of the mysid shrimp *A. thailandica*, the numbers of which; however, fluctuated monthly as a result of major recruitments of juveniles during particular months. Unlike temperate species but similar to other tropical mysid species, *A. thailandica* reproduces throughout the year. Thus, the Matang mangrove serves as spawning, nursery, and maturation grounds for this small, but trophically important species of mysid shrimp. It is important that further studies be carried out to elucidate its role in the mangrove food web.

Acknowledgments: We are grateful to the Univ. of Malaya, Kuala Lumpur for research facilities and transport. We wish to thank the following persons for field and laboratory assistance: Mr. C.H. Lee (boatman), Ms. S.Y. Chai, and Mr. H.W. Teoh. This study forms part of the PhD research carried out by the 1st author, and was supported by research grants from the Univ. of Malaya and the Japan International Research Center for Agricultural Sciences (Tsukuba, Japan) given to the 2nd author. The 1st author expresses gratitude to Thaksin Univ., Phattalung, Thailand, for providing her a PhD scholarship.

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