Lunar Tidal Rhythms of the mysid Shrimp (*Acanthomysis thailandica*) Population Structure and Reproduction in a Tropical Mangrove, Malaysia

Tueanta Ramarn, Chong Ving Ching, and Yukio Hanamura

***Abstract*—**Population structure and reproduction of the mysid shrimp *Acanthomysis thailandica* Murano, 1988 were studied at the Matang mangrove, Peninsular Malaysia. Mysid samples were collected weekly from 10 February – 7 March 2009 during dry period of NE monsoon and another series during the wet period from 1 – 23 December 2009. The population structure of *A. thailandica* comprised all developmental stages, from juvenile to empty female which had just shed its progeny. However, their proportions in the population changed with moon phase during both the dry and wet period of study. Immature and mature males were dominant at full moon (FM). Mature males still comprised the main group at the last quarter moon (3Q) during the dry period while juvenile and immature males formed the largest groups during the wet period. However, juveniles became the largest group at the new (NM) and first quarter moon (1Q) during the dry period indicating peak spawnings occurring at NM and 1Q. During the wet period, juveniles similarly constituted the main group at NM and 1Q during the wet period. These results suggest that the mysid shrimp spawns mainly during new moon and first quarter moon phase.

***Keywords*—** Mysida, population structure and reproduction

I. Introduction

Mysid shrimps (Crustacea: Mysida) are the major hyperbenthic organisms in many estuarine and coastal ecosystems [28], [26], [30], [36]. They play an important role in the trophodynamics of coastal ecosystems [20], [7], feeding on detritus, phytoplankton and zooplankton [8], [3], [6]. In turn, they serve as prey food for other marine organisms [1], thus providing the trophic link between primary producers and secondary consumers. In the Matang mangrove, mysid shrimps are found to be consumed by juvenile clupeid, sciaenid, mullid and gobiid fishes that use the mangrove as feeding ground [29]. The mangrove swamp also functions as an important habitat for juvenile John's snapper *Lutjanus johnii* Bloch, 1792, which are known to feed heavily on mysid shrimps [15].

Despite their high abundance in most coastal ecosystems and their play important role in the aquatic ecosystem, mysid shrimps are poorly studied, unlike penaeid shrimps which are the most researched crustacean of interest in the mangrove [21], [4], [29]. This is the result of their small size, taxonomic difficulty and non-obvious economic value. Published works on Malaysian mysid shrimps are markedly lacking. Hanamura and coworkers [30], [36] reported on the abundance and distribution of mangrove hyperbenthic crustaceans which included mysid shrimps. They further described the reproductive biology of mysid species of the genus *Mesopodopsis* in a Malaysian mangrove estuary [31] and sandy beach [34] which occurred throughout the year. *Acanthomysis thailandica* Murano, 1988 is the dominant mysid species in the Matang mangrove estuary [26], and information regarding its reproduction is particularly desirable to understand their recruitment and ecology. However, in the tropical zone, little is known about the life history and reproduction of mysids, because continuous breeding throughout the year [10], [34], [27] often makes it difficult to study reproduction in detail by monthly sampling. Based on monthly sampling, Ramarn and coworkers [27] reported that the brooding females of *A. thailandica* occurred with juveniles in all monthly sampling, indicating that reproduction was year round. The present study dealt with weekly samplings to examine the lunar tidal effect on the population structure and reproduction of *A. thailandica* in the Matang mangrove, Peninsular Malaysia.

II. Material And Methods

Samples collection

The Matang Mangrove Forest Reserve (MMFR) in the Perak States is a complete mangrove in Malaysia. It is located on the west coast of Peninsular Malaysia (4°50'N, 100°35'E) (Fig. 1). 24–h samplings at 3-h intervals were carried out at a mudflat (S) in the Matang mangrove on 10-11 February (spring, full moon), 21-22 February (neap, last quarter), 28 February – 1 March (spring, new moon) and 6-7 March 2009 (neap, first quarter) during the dry period of the north-east monsoon. Another series during the wet period was carried out

Tueanta Ramarn* is a Lecturer at Department of Biology, Faculty of Science, Thaksin University, Phatalung, 90120 Thailand. (*Corresponding author: Phone 66-7460-9600; Fax: 66-7469-3992; E-mail: tuantar@yahoo.com).

Chong Ving Ching is a Professor at Institute of Biological Science and Institute of Ocean & Earth Sciences, University of Malaya, Kuala Lumpur 50603, Malaysia. E-mail: chong@um.edu.my

Yukio Hanamura is a Senior Researcher at Japan International Research Center for Agricultural Science, Owashi 1-1, Tsukuba 350-8686 Japan. Present address: National Resarch Institute of Fisheries Science, Fisheries Research Agency 2-12-4 Fuku-ura, Kanazawa-ku, Yokohama 236-8648, Japan. E-mail: hanamura@affrc.go.jp

http://dx.doi.org/10.15242/IICBE.C414051

on 1-2 December (spring, full moon), 8-9 December (neap, last quarter), 15-16 December (spring, new moon) and 22-23 December (neap, first quarter) 2009. Replicate mysid samples were taken using a bottom mud sledge which sampled mysid shrimps at the bottom. The sledge net had a 0.53 x 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 borax-buffered 4% seawater-formalin solution [23].

Laboratory Analysis

In the laboratory, all mysid shrimps were sorted out under a stereomicroscope for identification and counting. The mysid shrimps were identified to the species level by using the following references: [19], [18], [25], [32], [33], [35]. The morphological details were examined using the compound microscope.

The total length (TL, mm) was measured from the anterior tip 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 (penis on the 8th thoracic limb rudimentary, 4th pleopod extended, and process masculinus present, but with no or few setae); (3) mature male (penis 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) [10], [16]. All examinations and measurements were made from more than 200 specimens, if available.

Sex ratio was expressed as number of females/number of mature males.

Data Analysis

Analysis of Variance (ANOVA) was conducted to compare the difference in total length among developmental stages, brooding females total length (F1, F2 and F3), egg or larval length within a sampling date. All data set were first tested for normality and homogeneity as required for parametric analysis [22]. Spearman's rank correlation test was used to determine correlations of female total length with brood size, and of brooding female total length with egg or larval length. Levels of significance were tested at p=0.05.

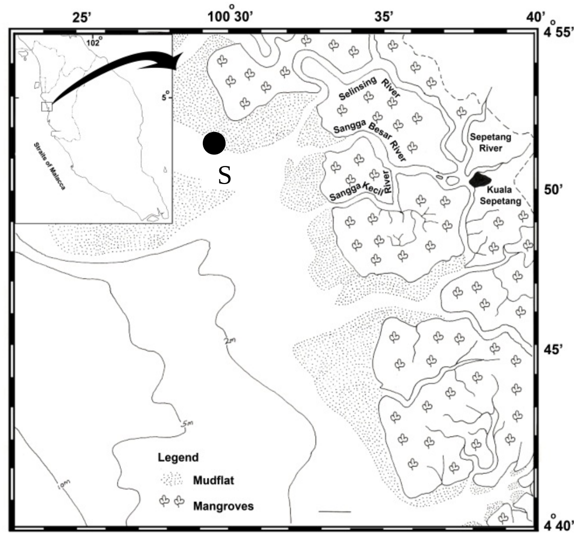

Fig. 1 Map showing the sampling station at the Matang mangrove, Peninsular Malaysia.

III. Results

Developmental stages and size

All developmental stages, from juvenile to empty female, were found during the study period. The total lengths (TL) of *A. thailandica* for various developmental stages are presented in Table 1 and 2. Juveniles had the smallest body size that ranged from 2.07±0.06 mm at the full moon (FM) dry period, while the longest juvenile was found at the last quarter moon (3Q), 2.57±0.04 mm during dry period.

TABLE I
TOTAL LENGTH OF *ACANTHOMYSIS THAILANDICA* DURING DRY PERIOD (10 FEBRUARY-7 MARCH 2009). DENOTE: JUV=JUVENILE, IMM=IMMATURE MALE, IMF=IMMATURE FEMALE, MAM=MATURE MALE, MAF=MATURE FEMALE, BR=BROODING FEMALE AND EMP=EMPTY FEMALE.

Stage	Full moon	Last quarter	New moon	First quarter
Juv				
Mean	2.07±0.06	2.57±0.04	2.39±0.03	2.45±0.05
Min	1.60	2.51	1.82	1.98
Max	2.77	2.64	2.97	2.81
Imm				
Mean	3.53±0.06	3.54±0.05	3.19±0.04	3.17±0.10
Min	2.73	2.73	2.81	2.94
Max	4.20	4.03	3.99	3.65
Imf				
Mean	3.40±0.06	3.38±0.06	3.20±0.02	3.33±0.09
Min	2.98	2.94	2.81	3.02
Max	4.15	3.95	3.40	4.20
Mam				
Mean	4.83±0.06	4.37±0.05	4.87±0.06	4.30±0.10
Min	3.69	3.90	4.06	3.60
Max	5.75	4.94	5.94	4.85
Maf				
Mean	4.18±0.06	3.94±0.05	3.72±0.06	4.01±0.04
Min	3.70	3.45	3.10	3.85
Max	4.70	4.45	4.15	4.10
Br				
Mean	4.84±0.06	4.56±0.06	4.92±0.05	4.52±0.05
Min	4.31	4.06	4.35	4.40
Max	5.44	5.19	5.44	4.75
Emp				
Mean	4.97±0.05	4.56±0.04	4.88±0.07	4.50±0.03
Min	4.56	4.10	4.06	4.38
Max	5.63	5.31	5.63	4.56

http://dx.doi.org/10.15242/IICBE.C414051

In addition, the juvenile stage was significantly different in term of TL from other developmental stages at all sampling dates. Juveniles developed to immature male or females at approximately the same size, which ranged from 3.17 – 3.55 mm. Among mature mysids, the smallest mean TL was observed in the mature females, with total lengths that ranged from 3.72±0.06 to 4.18±0.06 mm, while mature males, brooding females and empty females had about the same size range for all sampling dates; their mean TL ranged from 4.30±0.10 to 5.03±0.08 mm.

TABLE II
TOTAL OF *ACANTHOMYSIS THAILANDICA* DURING THE WET PERIOD (1-23 DECEMBER 2009). DENOTE: JUV=JUVENILE, IMM=IMMATURE MALE, IMF=IMMATURE FEMALE, MAM=MATURE MALE, MAF=MATURE FEMALE, BR=BROODING FEMALE AND EMP=EMPTY FEMALE.

Stage	Full moon	Last quarter	New moon	First quarter
Juv				
Mean	2.15±0.07	2.33±0.04	2.54±0.04	2.54±0.04
Min	1.95	1.58	1.98	1.85
Max	2.61	2.81	2.97	2.94
Imm				
Mean	3.55±0.09	3.17	3.52±0.05	3.49±0.06
Min	2.44	2.31	2.73	3.07
Max	4.20	3.91	4.20	4.12
Imf				
Mean	3.20±0.06	3.20±0.05	3.38±0.05	3.47±0.06
Min	2.48	2.69	2.69	2.81
Max	3.78	4.07	3.78	4.20
Mam				
Mean	4.83±0.05	4.43±0.06	4.73±0.07	4.92±0.06
Min	4.25	3.88	4.06	2.81
Max	5.63	5.19	5.56	4.20
Maf				
Mean	4.06±0.03	3.74±0.06	4.08±0.05	4.05±0.05
Min	3.70	3.25	3.55	3.55
Max	4.55	4.30	4.60	4.95
Br				
Mean	4.84±0.06	4.17±0.0740	4.98±0.06	5.10±0.07
Min	4.38	6	4.38	4.38
Max	5.44	5.44	5.63	5.88
Emp				
Mean	4.76±0.07	4.68±0.07	5.03±0.08	4.95±0.08
Min	3.88	3.88	4.50	4.13
Max	5.63	5.63	5.75	5.88

Population structure during dry period (10 February-7 March 2009)

The mysid shrimp population comprised all developmental stages, from juvenile to empty female which had just shed its progeny, with densities that differed among lunar phases (Fig. 2). At FM, immature females and mature males formed the largest groups, each constituting ca. 20% of the mysid population, while mature females and brooding females made up 8.48 % and 9.77%, respectively. Juvenile, immature males and empty females contributed about equally to the population size (10.02%, 15.42% and 14.91%, respectively).

Mature males still comprised the largest group at 3Q (28%), followed by empty females (22.90%). Immature males, immature females, mature females and brooding females occurred in equal proportions in the mysid population (15.36%, 13.70%, 10.72% and 13.62%, respectively) while juveniles formed the smallest group (1 %).

Interestingly, juveniles contributed to the largest group (36%) at new moon (NM). Immature females (16.39%) and mature males (17.12%) were the next largest groups during this period. On the other hand, immature males, mature females, brooding females and empty females contributed less than 9% to the mysid population.

The high proportion of juveniles (31%) continued until the first quarter moon (1Q), while mature female formed the smallest group (5%). Like in NM, immature females and mature males formed the next largest groups, each contributing about 20% of the mysid population, while immature males, and brooding females occurred in about equal proportions (7–10%).

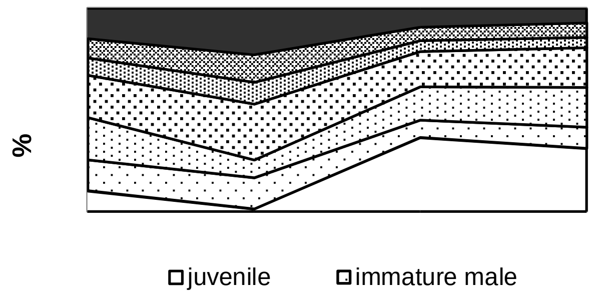

Fig. 2 Population structure of *Acanthomysis thailandica* during dry period in the Matang mangrove, Peninsular Malaysia.

Population structure during wet period (1-23 December 2009)

Population structure of *A. thailandica* during the wet period of the NE monsoon comprised all developmental stages (Fig. 3), similar to the population structure during the dry period, but differed in some way. At FM, mature male formed the largest group, up to 31.94% of mysid population, followed by immature male (20.70%), mature female (13.44%), immature female (11.23%) and brooding female (10.35%) while the empty female formed the smallest group (7.71%).

Juvenile contributed to the largest proportion in the mysid population at 3Q (27.8%) and further increased during NM (38.3%). Neither immature male nor immature female still ranked in second position.

In contrast, empty female was the smallest group at NM, making up only 2.52%.

The population structure at1Q was similar to 3Q and NM when juveniles formed the largest group (23.15%) followed by immature male (19.58%) and immature female (16.02%). However, mature male formed the smallest group (6.82%).

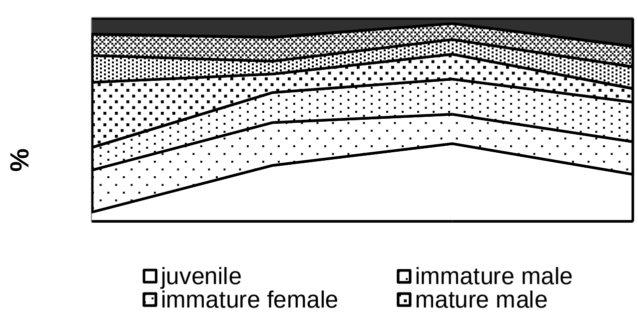

Fig. 3 Populations tructure of *Acanthomysis thailandica* during wet period in the Matang mangrove, Peninisular Malaysia.

http://dx.doi.org/10.15242/IICBE.C414051

Sex ratio

Sex ratio of *A. thailandica* varied among lunar phases. The highest sex (F:M) ratio was found at 1Q (1.72), followed by FM (1.59) , NM (1.26) and 1Q (1.00) during the dry period. During the wet period, the sex ratio was also the highest at 1Q (5.04) followed by 3Q (2.80), NM (1.46) and FM (0.99).

Brooding female and brood size

Brooding female TL was compared among female carrying egg (F1), eyeless larvae (F2) and eyed larvae (F3) for each sampling week. The results revealed that TL varied among the three brooding female stages and the four lunar phases (Table 3 and 4). No significant increased in TL among brooding females were observed (ANOVA, p>0.05). Mean TL of F1 brooding females ranged from 4.35±0.06–4.75±0.05 mm. during the dry period and 4.49±0.07–4.76±0.10 mm. during wet period. The smallest F2 was observed at 3Q during both the dry (4.45±0.10 mm) and wet period of study (4.56±0.11 mm). On the other hand, the biggest mysid shrimps were observed at NM (5.01±0.09 mm) during the dry period and 1Q (4.96±0.36 mm) during the wet period. For F3 female, the smallest mysid were observed at 1Q (4.45±0.05 mm) and 3Q (4.79±0.16 mm) for dry and wet period, respectively. The largest individuals were found during new moon (4.89±0.07 mm) and first quarter (4.99±0.05 mm) for dry and wet period, respectively.

Brood sizes were variable between the seasonal periods and not significantly differed among three brooding stages (ANOVA, $F_{2,43}$=0.41, p>0.05 for dry period and $F_{2,43}$=1.60, p<0.05) for wet period. The mean brood size for F1, F2 and F3 were 10.62±0.94, 9.67±1.00 and 11.10±1.23 individuals/brood and the mean brood size for three brooding stages during wet season were 10.37±0.60, 8.83±0.65 and 10.67±1.30 individuals/brood.

In addition, the brood size of all brooding stages was not significantly correlated (Spearman's rank correlation test, p>0.05) with female TL for both dry and wet period (Fig. 4 and 5). Thus, brood size did not increase with increasing female TL.

TABLE III
BROODING FEMALE TOTAL LENGTH (MM) OF *ACANTHOMYSIS THAILANDICA* IN THE MATANG MANGROVE ESTUARY DURING DRY PERIOD (10 FEBRUARY – 10 MARCH 2009).

Stage	Full moon	Last quarter	New moon	First quarter
F1 female				
Mean	4.75±0.05	4.55±0.13	4.69±0.11	4.35±0.16
Min	4.35	4.25	4.20	4.05
Max	5.00	4.98	5.10	4.60
F2 female				
Mean	4.82±0.05	4.45±0.10	5.01±0.09	4.65±0.05
Min	4.50	4.30	4.60	4.65
Max	5.04	4.85	5.82	4.75
F3 female				
Mean	4.84±0.05	-	4.89±0.07	4.45±0.05
Min	4.75		4.55	4.45
Max	4.92		5.40	4.60

TABLE IV
BROODING FEMALE TOTAL LENGTH (MM) OF *ACANTHOMYSIS THAILANDICA* IN THE MATANG MANGROVE ESTUARY DURING WET PERIOD (1-23 DECEMBER 2009).

Stage	Full moon	Last quarter	New moon	First quarter
F1 female				
Mean	4.73±0.04	4.49±0.07	4.60±0.11	4.76±0.10
Min	4.45	4.00	3.20	4.15
Max	5.28	5.00	4.95	5.16
F2 female				
Mean	4.76±0.06	4.56±0.11	4.88±0.05	4.96±0.36
Min	4.40	4.15	4.55	4.15
Max	5.34	5.10	5.22	5.52
F3female				
Mean	4.81±0.21	4.79±0.16	4.90±0.08	4.99±0.05
Min	4.40	4.50	4.65	4.85
Max	5.10	5.22	5.40	5.28

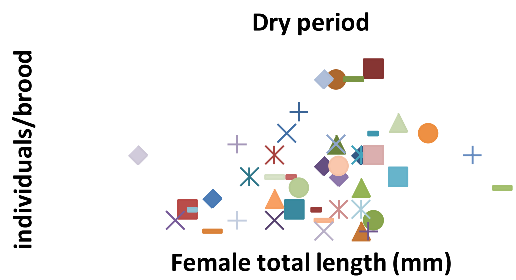

Fig. 4. Relationship between the total length of females and number of larvae (pooled data from all sampling weeks) during dry period. R_s = correlation coefficient = 0.26; sample size=46.

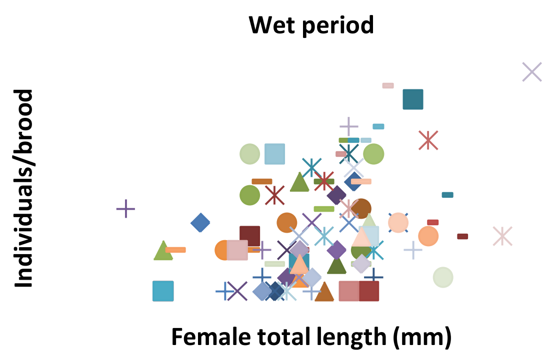

Fig.5. Relationship between the total length of females and number of larvae (pooled data from all sampling weeks) during wet period. R_s = correlation coefficient = 0.22; sample size=87.

Egg and larval length

Figure 6 shows the mean length of egg, eyeless and eyed larvae in the mysid marsupium sampled at four lunar phases during the dry and wet period, The results showed that larval length increased with embryonic development (i.e. from egg to eyed larva). However, the length of eyeless and eyed larval length was not significantly different during the dry period (post –hoc Turkey HSD test, p>0.05). In contrast, eyed larvae were significant longer than eyeless larvae during the wet period for all sampling dates (w1 – w4). The range in mean lengths of eggs, eyeless larvae and eyed larvae for the four sampling occasions during wet period were 0.25±0.002 to

0.26±0.001, 0.48±0.03 to 0.57±0.00 mm and 0.64±0.02 to 0.68±0.06 mm for eggs, eyeless and eyed larvae, respectively. These results suggested that larvae in the marsupium grew faster during the wet period.

Egg and larval length were not related (Spearman's rank correlation test, $p>0.50$) to female TL. Spearman's rank correlations of female TL with egg length, eyeless larvae length and eyed larval length were respectively 0.22 (n=245), 0.21 (n=167) and 0.01 (n=132) during dry period, and 0.32 (n=535), 0.34 (n=298) and 0.23 (n=155) during wet period.

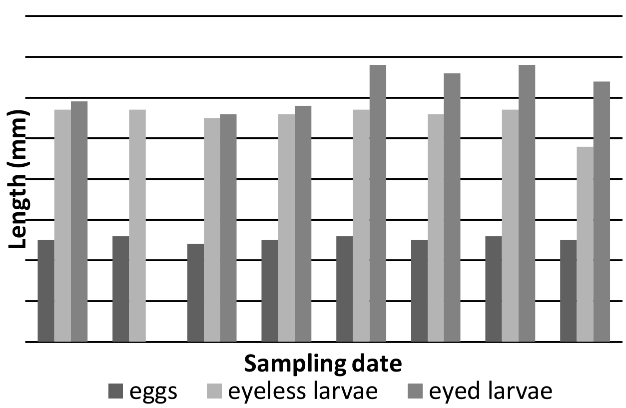

Fig. 6. Weekly variations of length of egg, eyeless and eyed larvae of mysid shrimps *Acanthomysis thailandica* in the Matang estuary during the study period. Sampling date on x-axis denoted by D1=full moon, dry period; D2=Last quarter, dry period; D3=New moon, dry period; D4=First quarter, dry period; w1=Full moon, wet period; w2=Last quarter, wet period; w3=New moon, wet period; w4=First quarter, wet period.

IV. Discussion

Reproduction in mysids appears to differ between the temperate and tropical zones. In general, reproduction in temperate mysids produces three distinct generations, over-wintering, summer and spring generations, in a year [14], [9]. On the other hand, tropical mysid recruitments are observed year round [31], [34], [27] making it difficult to determine the number of generations per year. For mysid species with a wide latitudinal distribution, their life cycles are more complex at lower latitudes due to almost continuous breeding throughout the year [10], [14], [5], [16]. This type of life history, which usually occurs in littoral ecosystems at latitudes below 40º, leads to overlapping generations that are rarely distinguishable in field data; only additional laboratory culture to determine growth rate and brood production can reliably determine the number of generations [13]. Based on weekly samplings combined with growth rate studies in the laboratory, Sudo and coworkers [10] reported that the spawning and recruitment of *Orientomysis robusta* (Murano, 1984) occurred throughout the year with as many as 19 overlapping cohorts recognizable over the annual cycle.

In general, juveniles formed the largest group in most mysid populations [31], [34], [24], [27]. This may indicate continuous recruitment in mysid populations whose developmental stages are not spatially segregated. In the present study, juveniles of *A. thailandica* formed the largest group during the new moon, indicating more spawnings occurring during this lunar phase. Brooding females made up the highest proportion during the last quarter moon, hence, resulting in massive spawnings and the highest number of juveniles during the new moon.

The present study thus shows that the observed year-round breeding in *A. thailandica* is a cumulative effect resulting from more or simultaneous spawnings at the lunar phase level. How the new moon illicits the spawning response in the mysid is however untested, although predation could be one reason. Spawnings under the cover of total darkness during moonless nights have been reported in many organisms [2].

In general, the body length of brooding females increases as the embryos develop in the marsupium [31], [27]. Brooding females do not show significant growth in body length, while embryonic development inside the marsupium appears independent of the brooding female size. Any increase in the body size is possibly due to intermolt growth resulting from the stretching of the abdominal joints [12] since the brooding female does not molt. Hanamura and coworkers [33] suggested that the size increment observed in the breeding female population of *Mesopodopsis orientalis*, is not due to somatic growth but rather a phenomenon caused by the higher mortality of small females as compared to larger females.

In general, population structure should be studied over a reasonably long period, at least one year or more, to obtain reproducible results. The sampling programme, within which the present study reports only the preliminary results, however, covered not only the lunar and seasonal effect, but also the diel and tidal effects (not reported here).

Acknowledgment

We are grateful to the University of Malaya, Malaysia, 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 research was supported by grants from the University of Malaya and the Japan International Research Center for Agricultural Science (Tsukuba, Japan) given to the 2nd author.

References

[1] B. Beyst, D. Buysse, A. Dewicke, and L. Mees, "Surf zone hyperbenthos of Belgian sandy beaches: Seasonal Patterns," *Estuarine Coastal and Shelf Science*, vol. 53, 877-895, 2001. http://dx.doi.org/10.1006/ecss.2001.0808

[2] C.A. Jacoby, ans J.G. Greenwood, "Emergent zooplankton in Moreton Bay, Queensland, Australia: seasonal, lunar and diel patterns in emergence and distribution with respect to substrata," *Marine Ecology Pregress Series*, vol.51, 131-154, 1989. http://dx.doi.org/10.3354/meps051131

[3] C.A. Siegfried, and M.E. Kophache, "Feeding of *Mysis mercedis* (Holmes)," *Biological Bulletin*, vol. 159, pp. 193-205, 1980. http://dx.doi.org/10.2307/1541018

[4] C.H. Faunce, and J.E. Serafy, "Mangroves as fish habit: 50 years of field Studies," *Marine Ecology Progress Series*, vol.318, 1-18, 2006. http://dx.doi.org/10.3354/meps318001

[5] C. San Vicente, and J. C. Sorbe, "Biology of the suprabenthic mysid *Schistomysis spiritus* (Norman, 1860) in the southeastern part of the Bay of Biscay," *Scientia Marina*, vol. 59(1): 71-86, 1995.

[6] D.C. Lasenby, and R.R. Langford, "Feeding and assimilation of *Mysis relicta*," *Limnology and Oceanography*, vol. 18, pp. 280-285, 1973. http://dx.doi.org/10.4319/lo.1973.18.2.0280

[7] E. Fanelli, J.E. Cartes, F. Badalamenti, P. Rumolo, and M. Sprovieri, "Trophodynamics of suprabenthic fauna on coastal muddy bottoms of the southern Tyrrhenian Sea (western Mediterranean)," *Journal of Sea Research*, vol. 61, 174-187, 2009. http://dx.doi.org/10.1016/j.seares.2008.10.005

[8] E. Kouassi, M. Pagano, L. Saint-Jean, and J.C. Sorbe, "Diel vertical migrations and feeding behavior of the mysid *Rhopalophthalmus africana* (Crustacea: Mysidacea) in a tropical lagoon (Ebrie, Cote d' Ivoire)," *Estuarine, Coastal and Shelf Science*, vol. 67, 355-368, 2006. http://dx.doi.org/10.1016/j.ecss.2005.10.019

[9] F, Baldó, L.J. Taracido, A.M. Arias and P. Drake, "Distribution and life history of the mysid *Rhopalophthalmus mediterraneus* in the Guadalquivir estuary (SW Spain),"*Journal of Crustacean Biology*, vol. 21, 1961-1972, 2001. http://dx.doi.org/10.1651/0278-0372(2001)021[0961:DALHOT]2.0.CO;2

[10] H, Sudo, N. Kajihara, and M. Noguchi, "Life history and production of the mysid *Orientomysis robusta*: high P/B ratio in a shallow warm-temperate habit of the Sea of Japan," *Marine Biology*, vol. 158, 1537-1549, 2011. http://dx.doi.org/10.1007/s00227-011-1669-8

[11] J. Mauchline, "Inter-molt growth of species of Mysidacea (Crustacea)," *Journal of the Marine Biology Association of the United Kingdom*, vol. 53, 569-572, 1973 http://dx.doi.org/10.1017/S002531540005877X.

[12] J. Mauchline, "The broods of British Mysidacea (Crustacea)," *Journal of the Marine Biology Association of the United Kingdom*, vol. 53, 801-817, 1973. http://dx.doi.org/10.1017/S0025315400022487

[13] J. Mauchline, "The biology of mysids," *Advancess in Marine Biology*, vol. 8, 3-369, 1980.

[14] J. Mees, Z. Abdulkerim, and O. Hamerlynck, "Life history, growth and production of *Neomysis integer* in the Westerschelde estuary (SW Netherlands)," *Marine Ecology Progress Series*, vol. 109, 43-57, 1994. http://dx.doi.org/10.3354/meps109043

[15] K. Kiso, and M-I. Mahyam, "Distribution and feeding habits of juvenile and young John's snapper *Lutjanus johnii* in the Matang mangrove estuary, west coast of peninsular Malaysia," *Fisheries Science*, vol. 69, 563-568, 2003. http://dx.doi.org/10.1046/j.1444-2906.2003.00657.x

[16] L. Delgado, G. Guerao, and C. Ribera, "Biology of the mysid *Mesopodopsis slabberi* (van Beneden, 1861) (Crustacea, Mysidacea) in a coastal lagoon of the Ebro delta (NW Mediterranean)," *Hydrobiologia*, vol. 357, 27-35, 1997. http://dx.doi.org/10.1023/A:1003118332417

[17] L.L. Chew, V.C. Chong, and Y. Hanamura, "How important are zooplankton to juvenile fish nutrition in mangrove ecosystem?," *JIRCAS Working Report*. vol. 56, 7-18, 2007.

[18] M. Murano, "Mysidacea from Thailand with descriptions of two new species," *Crustaceana*, vol. 55, 293-304, 1988. http://dx.doi.org/10.1163/156854088X00393

[19] N. Ii, "*Fauna Japonica: Mysidacea (Crustacea)*," Biogeographical Society of Japan, 1964.

[20] P. Drake, A.M. Arias, F. Baldo, J.A. Cuesta, A.R. Rodriguez, A. Silva-Garcia, I. Sobrino,D. Garcia-Gonzalez, and C. Fernandez-Delgado, "Spatial and temporal variation of the neckon and hyperbenthos from temperate European estuary with regulated freshwater inflow," *Estuaries*, vol. 25(3), 451-468, 2002. http://dx.doi.org/10.1007/BF02695987

[21] P. Ronnback, A. Macia, G. Almqvist, L. Schultz, and M. Troell, "Do penaeid shrimps have a preference for mangrove habitats? Distribution pattern analysis on Inhaca Island, Mozambique," *Estuarine, Coastal Shelf Science*, vol.3**,** 427-436, 2002. http://dx.doi.org/10.1006/ecss.2001.0916

[22] R. Sokal and F.J. Rolf, "*Biometry*," San Francisco, CA. W H Freeman, 1998.

[23] S. A. Grabe, W.W. Price, E.A.A. Abdulqader, and R.W. Heard, Jr., "Shallow-water Mysida (Crustacea:Mysidacea) of Bahrain (Arabian Gulf): species composition, abundance and life history characteristics of selected species," *Journal of Natural History*, vol. 38, 2315-2329, 2004. http://dx.doi.org/10.1080/00222930310001625932

[24] S.A. Pothoven, G.L. Fahnenstiel, H.A. Vanderploeg and M. Luttenton, "Population dynamics of *Mysis relicta* in Southeastern lake Michigan, 1995-1998," *Journal of Great Lakes Resaearch*, vol. 26, pp. 357-365, 2000. http://dx.doi.org/10.1016/S0380-1330(00)70700-3

[25] T.K. Fukuoka, and M. Murano, "Taxonomic position of *Acanthomysis quadrispinosa* and establishment of a new genus *Notacnthomysis* for *A. hodgarti* and *A. laticauda* (Crustacea: Mysidae)," *Species Diversity*, vol. 5, 23-37, 2000.

[26] T. Munilla, andC.S. Vicente, C.S, "Suprabenthic biodiversity of Catalan beaches (NW Mediterranean)," *Acta Oceanologica*, vol.27, 81-91, 2005. http://dx.doi.org/10.1016/j.actao.2004.09.006

[27] T. Ramarn, V.C. Chong and Y. Hanamura, "Population structure and reproduction of the mysid shrimps *Acanthomysis thailandica* (Crustacea: Mysidae) in a tropical mangrove estuary, Malaysia," *Zoological Studies*, vol. 51(6), 768-782, 2012.

[28] U. M. M. Azeiteiro, and J.C. Marques, "Temporal and spatial structure in the suprabenthic community of a shallow estuary (western Portugal: Mondego river estuary)," *Acta Oceanologica*, vol. 20(4), 333-342., 1999 http://dx.doi.org/10.1016/S1146-609X(99)00133-2.

[29] V.C. Chong, "Mangroves - fisheries linkages – the Malaysian perspective," *Bulletin of Marine Science*, vol. 80, 775-772, 2007.

[30] Y. Hanamura, R. Siow, and P-E. Chee, "Abundance and spatio-temporal distribution of hyperbenthic crustaceans in the Merbok and Matang mangrove estuaries, Malaysia," *JIRCAS Working Report*, vol. 56, 35-42, 2007.

[31] Y. Hanamura, R. Siow and P-E, Chee, "Reproductive biology and seasonality of the Indo-Australasian mysid *Mesopodophsis orientalis* (Crustacea: Mysida) in a tropical mangrove estuary, Malaysia, *Estuarine, Coastal and Shelf Science*, vol. 77, pp. 467-474, 2008a. http://dx.doi.org/10.1016/j.ecss.2007.10.015

[32] Y. Hanamura, N. Koizumi, S. Sawamoto, R. Siow and P-E. Chee, "Reassessment of the taxonomy of *Mesopodopsis orientalis* (Tattersall, 1908) (Crustacea, Mysida) and proposal of a new species for the genus with an appendix on *M. zeylanica* Nouvel, 1954," *Journal of Natural History*, vol. 42, 2461-2500, 2008b. http://dx.doi.org/10.1080/00222930802277608

[33] Y. Hanamura, K. Fukuoka, R. Siow, and P-E. Chee, "Re-description of a little-known Asian estuarine mysid *Gangemysis assimilis* (Tattersall, 1908) (Crustacea, Mysida) with a range extension to the Malay Peninsula," *Crustacean Research*, vol. 37, 35-42, 2008c.

[34] Y. Hanamura, R. Siow, P-E, Chee and F.M. Kaasim, "Seasonality and biological characteristics of the shallow-water mysid *Mesopodopsis orientalis* on a tropical sandy beach, Malaysia, *Plankton and Benthos Reaserh* , vol. 4, pp. 53-61, 2009. http://dx.doi.org/10.3800/pbr.4.53

[35] Y. Hanamura, M. Murano, and A. Man, "Review of eastern Asian species of mysid genus *Rhopalophthalmus* Illig 1906 (Crustacea: Mysida) with descriptions of three new species," *Zootaxa*, vol. 2788, 1-37, 2011.

[36] Y. Hanamura, K. Tanaka, A. Man, and F. M. Kassim, "Ecological characteristics of hyperbenthic crustaceans in Mangrove estuaries on the North-west coast of Peninsular Malaysia: an Overview," *JIRCAS Working Report*, 75, vol. 25-34, 2012.