Aquatic Animals

水生動物 第2024巻
令和6年10月

Alternation of a long life generation and some short life generations in a year in small penaeid shrimps in Japan

Hideo Sakaji

Fisheries Resources Institute, Japan Fisheries Research and Education Agency, 2-12-4 Fukuura, Kanazawa, Yokohama, 236-8649 Japan

e-mail: sakaji_hideo54@fra.go.jp

Abstract

Shrimp species of the penaeid genera *Metapenaeopsis* Bouvier, 1905 and *Trachysalambria* Burkenroad, 1934 are important for local fisheries in Asian countries. These genera include an abundant number of species, but life history information is reported only for the limited species. In this study, the body proportions of carapace length (CL) to body length (BL) and CL to body weight (BW) and the seasonal changes of CL distributions are reported for the first time in *M. dura* Kubo, 1949, *M. toloensis* Hall, 1962, and *T. albicoma* (Hayashi and Toriyama, 1980) collected in Tosa Bay (33 °N, 133 °E), Pacific coast of Japan. These proportion formulae are useful for comparing body sizes in each species in other studies and for the application to fisheries catch data. Seasonal changes in CL distributions indicated that in these species, a long life generation from winter to summer with a half-year lifespan and several short life generations from summer to winter with a few months lifespan alternated in a year. Females were significantly larger than males in the long life generation in each species. It is important to collect possibly small sized specimens for finding such short life generations. It is necessary to investigate the maturation for ascertaining the repetition of the short life generations in these species.

Key words: *Metapenaeopsis*; *Trachysalambria*; growth; body proportion; life history

Introduction

Penaeid shrimps are mainly distributed in tropical shallow waters (Dall et al. 1990) and are important for economies and fisheries. Although *Penaeus* species with relatively large body sizes are handled commercially worldwide, *Metapenaeopsis* and *Trachysalambria* species with relatively small body sizes are handled almost locally near the fishing area (Hayashi 1992).

The forty-two species of penaeid shrimps are distributed in the adjacent waters of Japan (Hayashi 1992; Sakaji et al. 2000; Sakaji 2003). In *Metapenaeopsis* and *Trachysalambria*, *M. acclivis*, *M. barbata*, *M. dalei*, and *T. curvirostris* are the main target species for the small scale bottom trawlers operating in the shallow and calm area such as Inland Sea (Tokai and Sakaji 1989). The life history such as growth and maturation in the four species, hence, were reported from many localities in Japan (Yasuda 1949; Yatsuyanagi and Matsukiyo 1951; Maekawa and Yatsuyanagi 1953; Yatsuyanagi and Maekawa 1957; Yasuda 1958; Ikematsu 1963; Ishikawa and Ichimura 1971; Hamanaka 1977; Kosaka 1977; Matsumiya and Oka 1977; Kosaka 1979; Ueta 1987; Arie et al. 1990; Hiyama and Hayashi 1991; Sakaji et al. 1992; Kusakabe 1997; Sakaji 2001a, 2001b, 2003; Yamada et al. 2007; Hossain and Ohtomi 2008). The same information has also been reported from the foreign waters, western Korea (Kim et al 1984; Cha et al. 2004; Choi et al. 2005), and Taiwan (Wu 1984; Treng and Yeh 1995).

Except for the above four species, the life history information has been reported from Japanese waters for *M. aegyptia*, *M. lata*, *M. mogiensis*, *M. provocatria owstoni*, *M. sibogae*, *M. sinica* (Matsumiya and Oka 1977; Sakaji et al. 1994; Sakaji 2001a, 2003; Rahman and Ohtomi 2017, 2020). Similar information has been reported from foreign

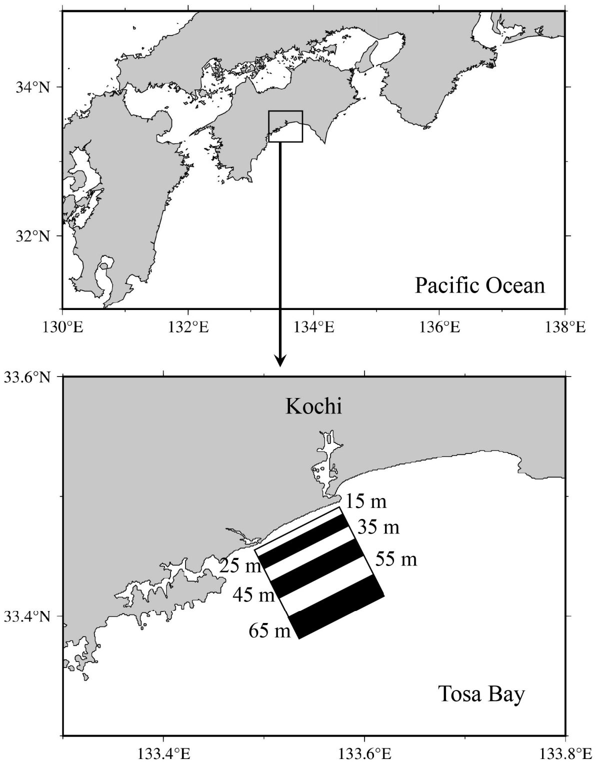

Fig. 1. Location and the depth classes of the sampling area of *Metapenaeopsis dura*, *M. toloensis*, and *Trachysalambria albicoma* in the central Tosa Bay, off Kochi, Pacific coast of Japan.

waters, *M. palmensis* in Taiwan (Chen et al. 2014), and *M. palmensis* and *M. rosea* in Australia (Watson and Keating 1989). *Metapenaeopsis* and *Trachysalambria* include abundant number of species (Crosnier 1987, 1991, 1994; Chan et al. 2016), however, information about life history is reported only in the limited species.

In this study, seasonal changes in carapace length distribution of *M. dur*a, *M. toloensis*, and *T. albicoma* in Tosa Bay (33 °N, 133 °E), Pacific coast of Japan, are reported, and their growth and life span are discussed. Body proportions of carapace length (CL) to body length (BL) and CL to wet body weight (BW) are also given. The growth and the body proportions of these species are reported for the first time, although the growth of *T. albicoma* has been reported previously (Toriyama 1980), with a different result from this study. Detailed information about the distribution depth in Tosa Bay is additionally described in *M. toloensis*, on the other hands in *M. dura* and *T. albicoma,* it was already described in Sakaji (2003).

Materials and Methods

Shrimp specimens were collected from the bottom of central Tosa Bay, off Kochi, Pacific coast of Japan, at depth classes of 15 m, 25 m, 35 m, 45 m, 55 m, and 65 m (Fig. 1), monthly from April 1995 to March 1996 except for January 1996. All the operations were conducted after dark between 19:00 and 22:00. The sampling gear was a beam trawl, the opening width of the net was 5 m and the mesh size of the cod end was 5 mm, which was towed by a small fishing boat (5 tons weight) in 15 minutes at the speed of 2 nautical miles per hour. Specimens were kept in seawater with ice on board and transferred to the laboratory in Kochi.

Specimens were sorted, counted, and weighed for each species. Subsamples were randomly selected in each depth class and fixed in 10 % formalin solution. For the fixed specimens, CL (mm) from the posterior orbital margin to the dorsal posterior end of the carapace, BL (mm) from the posterior orbital margin of the carapace to the posterior end of the telson, and BW (g) were measured. Macroscopic observations of the absence or presence of petasma were used to determine sex, but sex of small specimens of *M. dura* and *T. albicoma* was often undetermined when the sample size of small specimens was large, because such method took a long time for determination of sex. Unfortunately, the samples of each sex in February and March 1996 and the samples of the male in April 1995 of *M. toloensis* were not measured due to loss of the specimens.

The body proportion formulae of CL versus BL and CL versus BW were calculated using the graph function of MS-Excel. The number of undetermined sex specimens was halved, and the number of CL measurements was increased to the total number of the specimens in each depth class, and then they were aggregated to create a monthly CL distribution (1.0

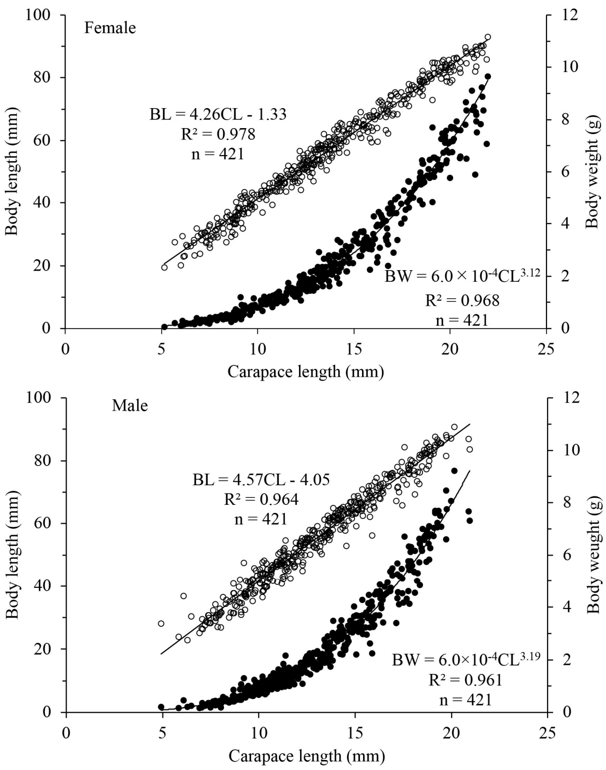

Fig. 2. Body proportions of carapace length (CL) versus body length (BL) and CL versus body weight (BW) of *Metapenaeopsis dura*, open and closed circles indicating CL versus BL and CL versus BW, respectively.

mm length class). Body size of each sex was compared by Welch's t-test using CL data from June, just before the current year's cohort appeared in July. Density was calculated as the number per 1,000 m^2 in each depth class in each month in *M. toloensis*.

Results

Metapenaeopsis dura

The ranges of the measurement were CL 5.2–22.0 mm, BL 19.3–93.0 mm, BW 0.1–9.6 g in female (n = 421), and CL 4.9–21.0 mm, BL 22.9–90.8 mm, and BW 0.2–9.2 g in male (n = 421). The body proportions of CL versus BL and CL versus BW and those coefficient determination (R^2) were as below (Fig. 2).

Female $\mathrm{BL} = 4.26\mathrm{CL} - 1.33$ $\quad R^2 = 0.978$

$\mathrm{BW} = 6.0 \times 10^{-4}\mathrm{CL}^{3.12}$ $\quad R^2 = 0.968$

Male $\mathrm{BL} = 4.57\mathrm{CL} - 4.05$ $\quad R^2 = 0.964$

$\mathrm{BW} = 6.0 \times 10^{-4}\mathrm{CL}^{3.19}$ $\quad R^2 = 0.961$

The two cohorts with some modes were annually recognized in the seasonal changes of the CL distribution, one was from April to September, and another was from July to March (Fig. 3). In April 1995, the CL range was divided into 8–11 mm and 13–16 mm in female and 9–12 mm and 13–17 mm in male, although each sample size was small. They

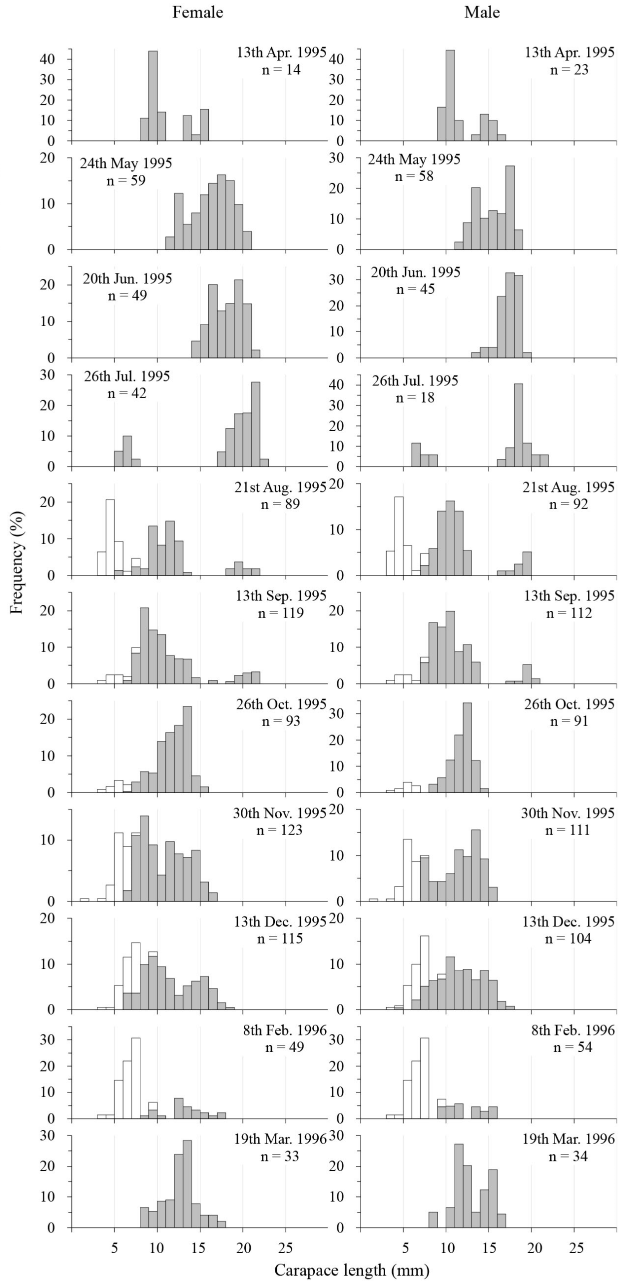

Fig. 3. Change of carapace length distribution from April 1995 to March 1996 of *Metapenaeopsis dura* in the central Tosa Bay, off Kochi, Pacific coast of Japan, grey and white bars indicating sex determined and undetermined specimens, respectively.

were combined with an increase of specimens in May, reaching 14–22 mm in female and 13–20 mm in male in June. In July, a new cohort appeared at 5–8 mm range in female and at 6–9 mm range in male, and the hitherto existed cohort reached 17–23 mm range in female and 16–22 mm range in male. In August, the smaller cohort was multimodal, and the CL range expanded to be 3–14 mm in female and 3–13 mm in male with the appearance of small sex-undetermined individuals, and the larger cohort decreased its frequency. In September, the smaller cohort was almost single modal at the 8–9 mm class in female and the 10–11 mm class in male. In October, the larger cohort disappeared, and the CL range was 3–16 mm with a mode at the 13–14 mm class in female and 3–15 mm with a mode at the 12–13 mm class in male. From November to February 1996, the cohort was multimodal, the CL range slightly expanded, and the frequency of small individuals gradually increased. In February 1996, the CL ranges were 3–18 mm in female and 3–16 mm in male with a clear mode at the 7–8 mm class in each sex. In March, small sex-undetermined individuals disappeared, and the CL range was 8–18 mm with a mode at the 13–14 mm class in female and 8–17 mm with modes at the 11–12 mm class and the 15–16 mm class in male.

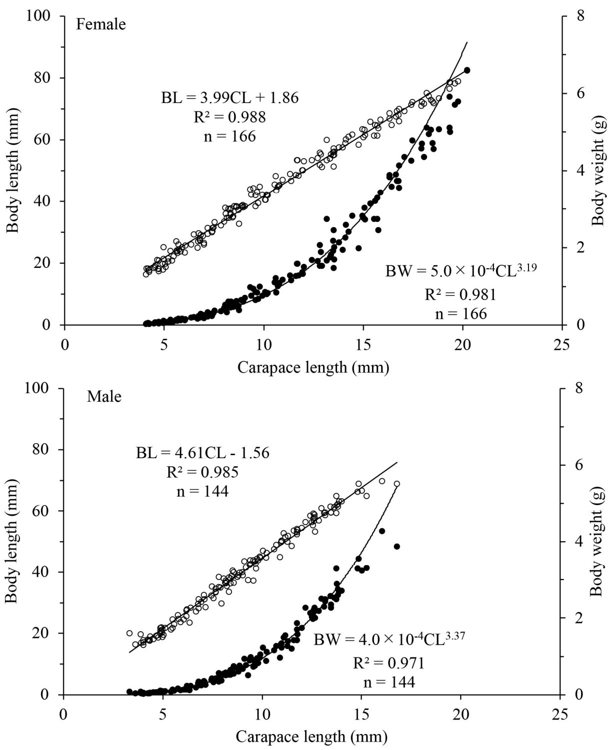

Fig. 4. Body proportions of carapace length (CL) versus body length (BL) and CL versus body weight (BW) of *Metapenaeopsis toloensis*, open and closed circles indicating CL versus BL and CL versus BW, respectively.

The growth of cohort, hence, was clear from April to July and March, although it almost stagnated and the modes of the cohort varied monthly from August to February. The recruitment was interrupted in September and October. In June just before the appearance of a new cohort, average values of CL were 18.2 mm in female (n = 49) and 17.3 mm in male (n = 45). They were significantly different from each other ($p = 3.10 \times 10^{-3}$), and female was larger than male.

Metapenaeopsis toloensis

The ranges of measurement were CL 4.1–20.2 mm, BL 16.4–82.6 mm, BW 0.03–6.6 g in female (n = 166), and CL 3.3–16.8 mm, BL 16.2–69.7 mm, and BW 0.03–4.3 g in male (n = 144). The body proportions of CL versus BL and CL versus BW and those coefficient determination (R^2) were as below (Fig. 4).

Female	$BL = 3.99CL + 1.86$	$R^2 = 0.988$
	$BW = 5.0 \times 10^{-4}CL^{3.19}$	$R^2 = 0.981$
Male	$BL = 4.61CL - 1.56$	$R^2 = 0.985$
	$BW = 4.0 \times 10^{-4}CL^{3.37}$	$R^2 = 0.971$

The two cohorts with some modes were annually recognized in the seasonal changes of the CL distribution, one was from April to July, and another was from July to December, although sample sizes were small and there were some missing data (Fig. 5). In April 1995, the CL range was 7–14 mm in female. Then, the CL range reached 13–21 mm in female and 10–17 mm in male in June. A new cohort appeared at 6–9 mm range in female and at 6–10 mm range in male, and the cohort existed until June disappeared in August. After that, the CL range of the cohort was

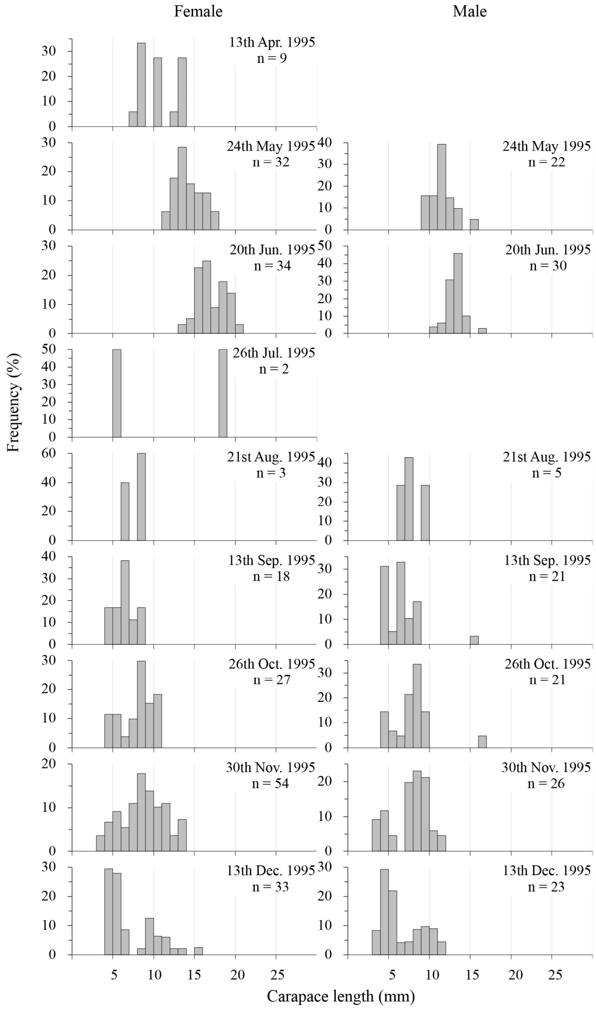

Fig. 5. Change of carapace length distribution from April to December 1995 of *Metapenaeopsis toloensis* in the central Tosa Bay, off Kochi, Pacific coast of Japan.

expanded by the appearance of large individuals and reached 3–14 mm in female and 3–12 mm in male with the highest mode at the 8–9 mm class in each sex in November. In male, a large individual appeared at the 15–16 mm class in September and at the 16–17 mm class in October, apart from the cohort. The CL range was 4–16 mm in female and 3–12 mm in male in December, but the highest mode was at the 4–5 mm class in each sex.

The growth of cohort, hence, was clear with no recruitment in female from April to June, although the modes were almost stable from August to November with the slight range expansion in female from October to December. In June just before the appearance of a new cohort, average values of CL in June were 17.1 mm in female (n = 34) and 13.2 mm in male (n = 30). They were significantly different from each other ($p = 3.08 \times 10^{-15}$), and female was larger than male.

The highest density in a month was at the 35 m depth class in April, May, June, October, and November in 1995, February and March in 1996; at the 25 m depth class in August, September, and December in 1995; at the 55 m depth class in July (Fig. 6). The highest four in these densities were at the 35 m depth class, and the highest was 28.1 individuals per 1,000 m^2 in February 1996. The densities at the 15 m and 65 m

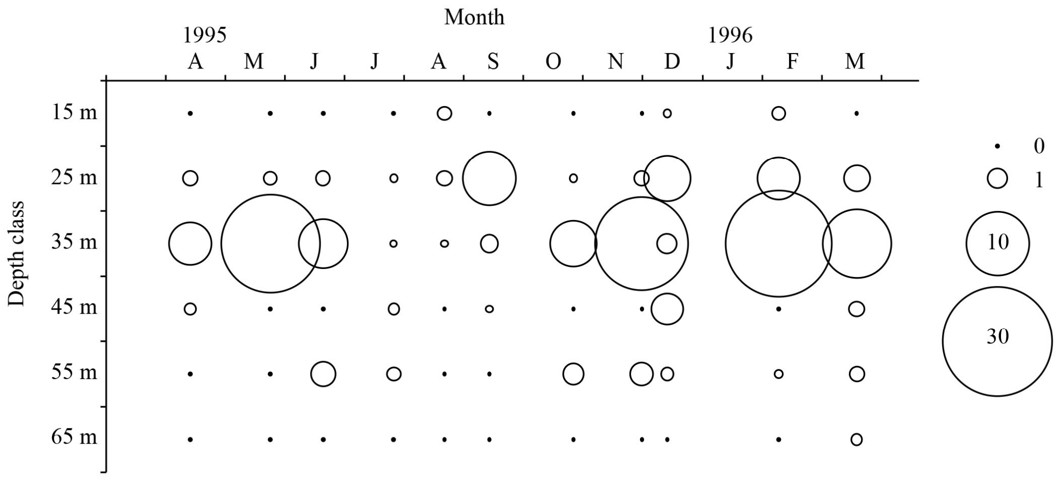

Fig. 6. Density (individuals per 1,000 m^2) of *Metapenaeopsis toloensis* in each depth class from April 1995 to March 1996 in the central Tosa Bay, off Kochi, Pacific coast of Japan.

depth classes were zero or very low under 0.5 individuals per 1,000 m^2. *M. toloensis*, hence, was distributed at the depth almost from 20 m to 60 m, mainly from 30 m to 40 m and the seasonal change of the depth range was unclear.

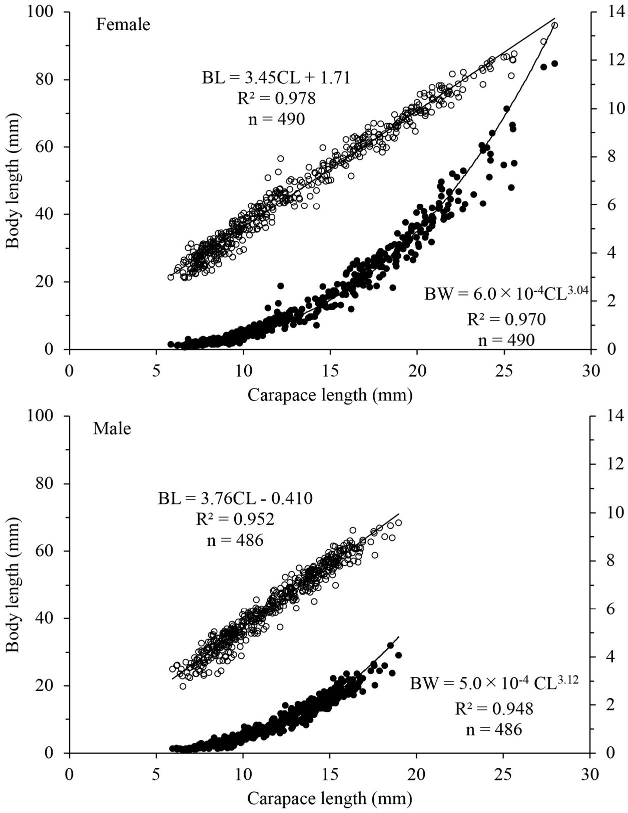

Fig. 7. Body proportions of carapace length (CL) versus body length (BL) and CL versus body weight (BW) of *Trachysalambria albicoma*, open and closed circles indicating CL versus BL and CL versus BW, respectively.

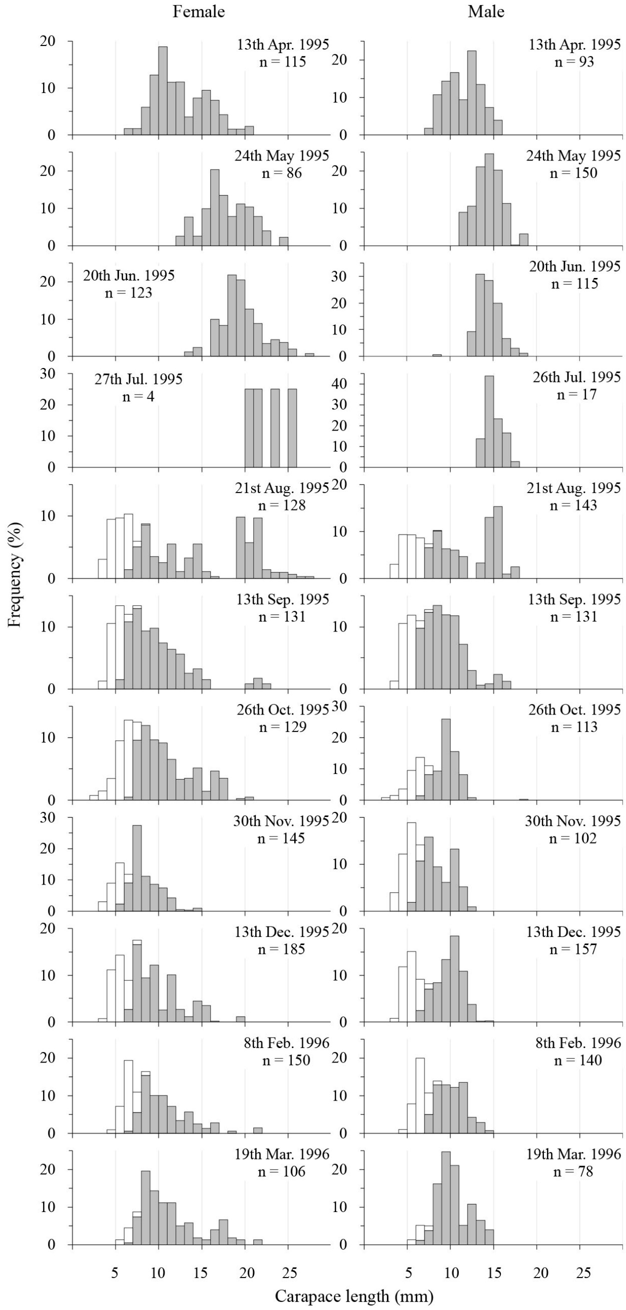

Fig. 8. Change of carapace length distribution from April 1995 to March 1996 of *Trachysalambria albicoma* in the central Tosa Bay, off Kochi, Pacific coast of Japan, grey and white bars indicating sex determined and undetermined specimens, respectively.

Trachysalambria albicoma

The ranges of measurement were CL 5.8–27.9 mm, BL 21.2–96.1 mm, BW 0.1–11.9 g in female (n = 490), and CL 6.0–19.0 mm, BL 19.8–68.5 mm, and BW 0.1–4.5 g in male (n = 486). The body proportions of CL versus BL and CL versus BW and those coefficient determination (R^2) were as below (Fig. 7).

Female $BL = 3.45CL + 1.71 \quad R^2 = 0.978$

$BW = 6.0 \times 10^{-4} CL^{3.04} \quad R^2 = 0.970$

Male $BL = 3.76CL - 0.410 \quad R^2 = 0.952$

$BW = 5.0 \times 10^{-4} CL^{3.12} \quad R^2 = 0.948$

The two cohorts with some modes were annually recognized in the seasonal changes of the CL distribution, one was from April to October, and another was from August to March (Fig. 8). In April 1995, the CL range was 6–21 mm with some modes in female and 7–16 mm with some modes in male. The CL range reached 12–25 mm in female and 11–19 mm in male in May. The CL range reached 20–26 mm in female but remained at 13–18 mm in male in June. In August, new cohort appeared, and its range was 3–17 mm in female and 3–12 mm in male, and the hitherto existed cohort reached 19–28 mm range in female but remained at 13–18 mm range in male. In September and October, the frequency of the larger cohort decreased, and the smaller cohort reached 2–18 mm range in female but remained at 2–13 mm range in male in October. In November, the larger cohort disappeared, and the frequency of the individuals larger than 10 mm in female decreased, and then the CL range was 3–15 mm with some modes in female and 3–13 mm with some modes in male. After that, the CL range gradually expanded and reached 5–22 mm with some modes in female but only reached 5–15 mm with some modes in male in March 1996.

The growth of cohorts, hence, was clear from April to July with no recruitment, although it almost stagnated from August to March with continuous recruitments and the body size in female was miniaturized in November. In June, which was before the appearance of a new cohort (August) and supplied enough numbers of specimens, average values of CL were 19.7 mm in female ($n = 123$) and 14.6 mm in male ($n = 115$). They were significantly different from each other ($p = 2.32 \times 10^{-50}$), and the females were larger than the males.

Discussion

The seasonal changes of CL distribution in *Metapenaeopsis dura*, *M. toloensis*, and *Trachysalambria albicoma* indicated that the cohorts of the current and the previous year were clearly separated, with the former appearing in summer and the latter disappearing in autumn. Such characteristics could result in a life span as a population of one year and a few months. On the other hand, smaller body sizes, multimodal CL distributions, and growth stagnation of the cohort were observed from August to February in *M. dura* and *T. albicoma* and from August to November in *M. toloensis*. During the period of growth stagnation of the cohort, recruitment was continuous in *M. toloensis* and *T. albicoma* but was interrupted once in September and October in *M. dura*, and miniaturization of the body size of the cohort occurred once in November in *T. albicoma*.

Smaller body size, multimodal CL distributions, growth stagnation of the cohort, and continuous recruitment from summer to winter were also reported in *M. dalei* in Tosa Bay with continuous occurrence of mature individuals. It was suggested that the repetition of some short life generations with smaller body size and rapid maturation resulted in such phenomena (Sakaji 2003).

In *T. albicoma*, the sudden appearance of a new cohort of CL 3–17 mm in females and 3–12 mm in males in August indicated the rapid growth of individuals in summer, and the disappearance of larger individuals in November indicated the disappearance of a previously recruited generation. Therefore, it was suggested that some short life generations with smaller body size repeated during the period of growth stagnation of the cohort from summer to winter, although maturation was not investigated in this study.

The bimodal CL distributions in the same period with an interruption of recruitment in September and October, suggested the repetition of some short life generations also in *M. dura*. Such short life generations from summer to autumn were expected in *M. toloensis* because of the bimodal CL distributions in the same period.

Fitting the multimodal CL distribution to mixed normal distributions was not used in this study, because it was difficult to relate the monthly modes of the CL distributions reasonably. It was therefore difficult to estimate how many generations alternated in this period, and it was only estimated that a long life generation from winter to summer with a half-year life span and some short life generations from summer to winter with a few month lifespan alternated in a year. A long generation was made from two recruitment groups in April in *M. dura* and *T. albicoma*, although they were combined in May.

There are studies on the pros and cons of the short life generation, which had smaller body sizes with rapid maturation and appeared in summer, in penaeid shrimps. The short life generation has been described in *M. barbata*, *Parapenaeopsis tenella*, and *T. curvirostris* (Yasuda 1956, 1958; Ikematsu 1963) and suggested in *T. curvirostris* (Kusakabe 1997), although it has not been confirmed in *P. tenella* and *T. curvirostris* (Ueta 1987, 1990; Hiyama and Hayashi 1991; Yamada et al. 2007). The minimum size, which was calculated by the body proportion of CL versus BL in Kusakabe (1997), on the body length distributions in *T. curvirostris* was 16.4 mm (CL 3 mm, Yasuda 1956), 13.3 mm (CL 2 mm, Ikematsu 1963), and 20 mm (Kusakabe 1997, 2008) in the studies where the short life generation was described or suggested. On the other hands, it was about 30 mm (Hiyama and Hayashi 1991), 22.7 mm (CL 5 mm, Yamada et al. 2007), and 25 mm (Ueta 1987) in the studies where the short life generation was not found. In the latter studies, the body sizes of the specimens were larger than those in the former studies. It is important to collect possibly small sized specimens for finding such short life generations and understanding the growth of such small sized shrimps.

The growths of *M. dura* and *M. toloensis* were described for the first time in this study. On the other hands, the growth of *T. albicoma* has been described in Tosa Bay (Toriyama 1980), as the life span was one year with rapid growth and two years with slow growth, and such result was different from this study. The numbers of the specimens smaller than BL 40 mm (CL 11.1 mm) in Toriyama (1980) were fewer than those in this study except for the duration from May to July, when the growth was conspicuous in both studies. Toriyama (1980) described that the specimens were sampled from landings at a fish market and from specimens of a research boat. The former was generally biased by the size selection by fishermen, and the latter was probably biased by a larger mesh size of the sampling gear than that in this study. It was suggested that such biased specimens in Toriyama (1980) reached the different result from this study, however, the mesh size was not described in the literature.

Sexual dimorphisms were recognized, and females were significantly larger than males in the long life generation in each species, moderately in *M. dura* and remarkably in *T. albicoma*. It is predicted that females may outnumber males in landings at a fish market due to the size selection by fishermen, especially in *T. albicoma*.

The body proportions of CL versus BL and CL versus BW are reported in *M. dura*, *M. toloensis*, and *T. albicoma* for the first time. These information are useful for comparing body sizes in each species in other studies and for the application to fisheries catch data.

The distribution depth of *M. toloensis* was reported to be 28 m in Thailand, 26–62 m in the Philippines, 37 m in Indonesia, 67 m in the Chesterfield Islands, from 8 m to 62 m in New Caledonia (Crosnier 1994), and they were located in tropical region. The distribution depth range in this study in Tosa Bay (20–60 m, mainly 30–40 m) was included in these previous records, although Tosa Bay (33 °N, 133 °E) is located in the temperate region and the water temperature from winter to spring is lower than that in the tropical region. It is possible that the growth of this species in the tropical region is different from the current study.

It is necessary to investigate the maturation in order to determine the repetition of the short life generations from summer to winter. Rearing experiments in an aquarium may be useful for estimating the life span of a short life generation.

Such investigations will reveal how many generations are repeated in a year for the species in this study.

Acknowledgements

I am grateful to Dr. Y. Takada, Fisheries Technology Institute, Japan Fisheries Research and Education Agency, Dr. S. Sawayama, Fisheries Resources Institute, Japan Fisheries Research and Education Agency, and anonymous reviewers for their valuable comments and suggestions, which have improved the manuscript. This work was supported by Nansei National Fisheries Research Institute (one of the predecessors of Fisheries Resources Institute, Japan Fisheries Research and Education Agency).

References

Arie, Y., Tokuda, M., Ishida, M. (1990). Biological study of small shrimps in Buzen Sea in Fukuoka Prefecture I. Maturation of *Trachypenaeus curvirostri*s. Bull. Fukuoka Pref. Buzen Fish. Exp. Sta. 3: 13–21. (In Japanese).

Cha, H. K., Oh, C. W., Choi, J. H. (2004). Biology of the cocktail shrimp, *Trachysalambria curvirostris* (Decapoda: Penaeidae) in the Yellow Sea of Korea. J. Mar. Biol. Assoc. UK. 84: 351–357.

Chan, T. Y., Cleva, R., Chu, K. A. (2016). On the *Trachysalambria* Burkenroad, 1934 (Crustacea, Decapoda, Penaeidae), with descriptions of three new species. Zootaxa 4150: 201–254.

Chen, H. S., Chen, C. Y., Chen, M. H. (2014). Life history tactics of southern velvet shrimp *Metapenaeopsis palmensis* (Crustacea, Decapoda) in the waters off southwestern Taiwan. Hydrobiologia 741: 177–191.

Choi, J. H., Kim, J. N., Ma, C. W., Cha, H. K. (2005). Growth and reproduction of the kishi velvet shrimp, *Metapenaeopsis dalei* (Rathbun, 1902) (Decapoda, Penaeidae) in the western sea of Korea. Crustaceana 78: 947–963.

Crosnier, A. (1987). Les espèces indo-ouest-pacifiques d'eau profonde du genre *Metapenaeopsis* (Crustacea Decapoda Penaeidae). Bull. Mus. natn. Hist. nat. Paris 4e sér 9 section A nº 2: 409–453.

Crosnier, A. (1991). Crustacea Decapoda: Les *Metapenaeopsis* indo-ouest-pacifiques sans appareil stridulant (Penaeidae). Deuxième partie. In: Crosnier A. (Ed), Résultats des Campagnes MUSORSTOM 9. Paris, France: Mém. Mus. natn. Hist. nat. (A) 152: 155–297.

Crosnier, A. (1994). Crustacea Decapoda: Les *Metapenaeopsis* indo-ouest-pacifiques avec un appareil stridulant (Penaeidae). In: Crosnier A (Ed.), Résultats des Campagnes MUSORSTOM 12. Paris, France: Mém. Mus. natn. Hist. nat. (A) 161: 255–337.

Dall, W., Hill, B. J., Rothlisberg, P. C., Staples, D. J. (1990). The biology of Penaeidae. Advances in Marine Biology, **27**, Academic Press, London.

Hall, D. N. F. (1962). Observations on the taxonomy and biology of some Indo West Pacific Penaeidae (Crustacea, Decapoda). Colonial Office Fisheries Publications, 17, Her Majesty's Office, London.

Hamanaka, Y. (1977). Studies on the shrimps in the western Wakasa Bay (the Tango-kai). On the distribution and ecology of *Metapenaeopsis acclivis* (Rathbun). Bull. Kyoto Inst. Ocean. Fish. Sci. Showa 50 fiscal year: 101–108. (In Japanese).

Hayashi, K. (1992). Dendrobranchiata crustaceans from Japanese waters. Seibutsu Kenkyusha, Tokyo. (In Japanese).

Hayashi, K., Toriyama, M. (1980). A new species of the genus *Trachypenaeus* from Japan (Crustacea, Decapoda, Penaeidae). Bull. Nansei Reg. Fish. Res. Lab. 12: 63–73.

Hiyama, S., Hayashi, Y. (1991). Growth of *Trachypenaeus curvirostris* in the western area of Inland Sea, Japan. Bull. Yamaguchi Pref. Naikai Fish. Exp. Sta. 19: 1–15. (In Japanese).

Hossain, M. Y., Ohtomi, J. (2008). Reproductive biology of the southern rough shrimp *Trachysalambria curvirostris* (Penaeidae) in Kagoshima Bay, southern Japan. J. Crust. Biol. 28: 607–612.

Ikematsu, W. (1963). Ecological studies on the fauna of Macrura and Mysidacea in the Ariake Sea. Bull. Seikai Reg. Fish. Res. Lab. 30: 1–124. (In Japanese with English synopsis).

Ishikawa, H., Ichimura, Y. (1971). Life history of *Trachypenaeus curvirostris* (Stimpson). Bull. Ibaraki Pref. Fish. Exp. Sta. Showa 45 fiscal year: 32–40. (In Japanese).

Kim, Y. H., Lee, S. D., Kim, B. G. (1984). Ecological study of the shrimp, *Trachypenaeus curvirostris*. Bull. Fish. Res. Dev. Agy. 32: 25–30. (In Korean with English abstract).

Kosaka, M. (1977). On the ecology of the penaeid shrimp, *Metapenaeopsis dalei* (Rathbun), in Sendai Bay. J. Fac. Mar. Sci. Technol. Tokai Univ. 10: 129–136. (In Japanese with English abstract).

Kosaka, M. (1979). On the ecology of the penaeid shrimp, *Trachypenaeus curvirostris* (Stimpson), in Sendai Bay. J. Fac. Mar. Sci. Technol. Tokai Univ. 12: 167–172. (In Japanese with English abstract).

Kubo, I. (1949). Studies on penaeids of Japanese and adjacent waters. J. Tokyo Coll. Fish. 36: 1–467.
Kusakabe, T. (1997). Growth and reproduction of southern rough shrimp *Trachypenaeus curvirostris* in Osaka Bay. Bull. Osaka Pref. Fish. Exp. Sta. 10: 59–69. (In Japanese).
Maekawa, K., Yatsuyanagi, T. (1953). Studies on the ecological of the useful aquatic animals in the Inland Sea of Yamaguchi Prefecture. Ecological study of *Trachypenaeus curvirostris* (S.), *Metapenaeopsis barbatus* (D.) and *Metapenaeopsis acclivis* (R.). J. Yamaguchi Pref. Naikai Fish. Exp. Sta. 5: 1–10. (In Japanese with English abstract).
Matsumiya, Y., Oka, M. (1977). Kishi-ebi, *Metapenaeopsis dalei* (Rathbun) and mogi-ebi *M. mogiensis* (Rathbun) found in Jogasheto of Iki Island. In: Biol. Soc. Nagasaki Pref. (Ed), Animals in Iki, comparing with those in Tsushima. Nagasaki, Japan: 337–342. (In Japanese with English synopsis).
Rahman, Md. M., Ohtomi, J. (2017). Reproductive biology of the deep-water velvet shrimp *Metapenaeopsis sibogae* (De Man, 1907) (Decapoda: Penaeidae). J. Crust. Biol. 37: 743–752.
Rahman, Md. M., Ohtomi, J. (2020). Ovarian maturation, size at sexual maturity and spawning season of *Metapenaeopsis provocatria owstoni* Shinomiya and Sakai, 2000 (Decapoda: Penaeidae). Crust. Res. 49: 109–120.
Sakaji, H. (2001a). Observation of the oocytes of the small penaeid shrimps *Metapenaeopsis aegyptia*, *M. barbata*, and *M. sinica*. Benthos Res. 56: 81–85.
Sakaji, H. (2001b). Maturation and spawning of the small penaeid shrimp *Metapenaeopsis dalei* in Tosa Bay, Pacific coast of southern Japan. Fish. Sci. 67: 444–448.
Sakaji, H. (2003). Fishery biological studies on penaeid shrimps in Tosa Bay, Pacific coast of Japan. Bull. Fish. Res. Agn. 6: 73–127. (In Japanese with English abstract).
Sakaji, H., Tokai, T., Sato, R. (1992). Growth and maturation of whiskered velvet shrimp *Metapenaeopsis barbata* (De Haan) in Aki-nada area, the Seto Inland Sea. Nippon Suisan Gakkaishi 58: 1021–1027. (In Japanese with English abstract).
Sakaji, H., Toriyama, M., Horikawa, H. (1994). A preliminary report of the life histories of *Metapenaeopsis provocatria longirostris* Crosnier and *M. lata* Kubo. Rep. Western Jpn. Demersal Fish Sec., Conf. Fish. Agn., Jpn. Gov. Fish. Res. Investigations 22: 1–12. (In Japanese).
Sakaji, H., Tsuchiya, K., Segawa, S. (2000). Penaeid fauna (Crustacea, Decapoda) of Tosa Bay and Urado Bay, Pacific coast of southern Japan. Bull. Natl. Res. Inst. Fish. Sci. 15: 11–39.
Tokai, T., Sakaji, H. (1989). The distribution of small penaeid shrimps in Inland Sea, Japan. Rep. 21st Inland Sea Fish. Study Meeting Nansei Reg. 55–70. (In Japanese).
Toriyama, M. (1980). On some morphological and ecological notes of the three species of the genus *Trachypenaeus* (penaeid prawn) in Tosa Bay. Bull. Nansei Reg. Fish. Res. Lab. 12: 75–91. (In Japanese with English abstract).
Treng, T. D., Yeh, S. Y. (1995). Growth parameters of red-spot shrimp, *Metapenaeopsis barbata*, from the adjacent waters off Taichung harbor. J. Fish. Soc. Taiwan 22: 53–68.
Ueta, Y. (1987). Reproduction and growth of *Trachypenaeus curvirostris* (Penaeidae, Decapoda, Crustacea) in Kii Channel. Suisan Zoshoku 35: 161–169. (In Japanese with English abstract).
Ueta, Y. (1990). Ecological information of *Parapenaeopsis tenella* (Penaeidae, Decapoda, Crustacea) in Kii Channel. Fish. Biol. Oceanogr. Southwestern Waters Jpn. 6: 55–64. (In Japanese with English summary).
Watson, R. A., Keating, J. A. (1989). Velvet shrimps (*Metapenaeopsis* spp.) of Torres Strait, Queensland, Australia. Asian Fish. Sci. 3: 45–56.
Wu, C. C. (1984). Survey of shrimp in Taiwan Strait and biological studies of thick-shell shrimp *Metapenaeopsis barbata* (de Haan). Bull. Taiwan Fish. Res. Inst. 37: 67–82. (In Chinese with English abstract).
Yamada, R., Kodama, K., Yamakawa, T., Horiguchi, T., Aoki, I. (2007). Growth and reproductive biology of the small penaeid shrimp *Trachysalambria curvirostris* in Tokyo Bay. Mar. Biol. 151: 961–971.
Yasuda, J. (1949). A biological note on the shrimp, *Trachypenaeus curvirostris* (Stimpson). Bull. Jpn. Soc. Sci. Fish. 15: 180–189. (In Japanese with English synopsis).
Yasuda, J. (1956). Fishery biological studies on shrimps in Inland Sea (II). Study in the ecology of each species. Bull. Naikai Reg. Fish. Res. Lab. 9: 1–81. (In Japanese).
Yasuda, J. (1958). Fishery biological studies on shrimps in Inland Sea. Bull. Naikai Reg. Fish. Res. Lab. 11: 171–198. (In Japanese with English summary).
Yatsuyanagi, T., Maekawa, K. (1957). Ecological study on the useful sea animals of Yamaguchi Pref. Inland Sea, 15. Ecological studies on the *Metapenaeopsis dalei* (Rathbun). J. Yamaguchi Pref. Naikai Fish. Exp. Sta. 9: 13–20. (In Japanese).
Yatsuyanagi, T., Matsukiyo, K. (1951). On the size, sex ratio and the relation between the carapace length and the weight of three kinds of shrimp

Metapenaeopsis barbatus (De Haan), *M. acclivis* (R.) and *Trachypenaeus curvirostris* (S.) caught in spring and autumn. Bull. Jpn. Soc. Sci. Fish. 16: 182–183. (In Japanese with English synopsis).

Received: 24 September 2024 | Accepted: 18 October 2024 | Published: 23 October 2024