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(Nisbah Kelamin pada Populasi *Nihonotrypaea japonica* (Ortmann, 1891) (Decapoda: Thalassinidea: Callianassidae), yang Berasal dari Mulut Sungai Shirakawa, Bagian Tengah Perairan Estuari Ariake, Kyushu Barat, Jepang)

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SEX RATIO IN THE POPULATION OF THE GHOST SHRIMP, *Nihonotrypaea japonica* (ORTMANN, 1891) (DECAPODA: THALASSINIDEA: CALLIANASSIDAE), COLLECTED FROM SHIRAKAWA RIVER, CENTRAL PART OF ARIAKE SOUND, WESTERN KYUSHU, JAPAN

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ABSTRACT

The present study was carried out on an intertidal sandflat developed at the mouth of Shirakawa River, central part of Ariake Sound, western Kyushu, Japan. The aim of the present study is to discuss the sex ratio in the population of *Nihonotrypaea japonica* from biological point of view. Sampling of the *N. japonica* population was conducted on a total of 21 occasions (spring tides) during the period from 20 April 1999 to 18 April 2000. With regards to the sampling interval, the study period can be grouped into 2 parts: (1) during 20 April – 22 November 1999, every 2 weeks, and (2) during 22 December 1999 – 18 April 2000, once a month. Sample collections were made by means of 'yabby pumps' during low tide on each occasion. The collected samples consist of 5628 females, 4385 males, and 346 sex-unidentified individuals, giving a female-biased sex ratio for the entire population. However, by dividing into several classes, there was a pattern of sex ratio, which seems to be related to reproductive aspect of the shrimp.

Keywords: Sex ratio, ghost shrimp, thalassinidea, callianassidae, *Nihonotrypaea japonica,* Ariake Sound.

ABSTRAK

Penelitian ini dilakukan di sebuah pantai intertidal berpasir yang terbentuk di muara Sungai Shirakawa, pada wilayah tengah perairan estuary Ariake Sound, Kyushu Barat, Jepang. Tujuan penelitian ini adalah untuk membahas nisbah kelamin populasi *Nihonotrypaea japonica* dari sudut pandang ilmu biologi. Pengambilan contoh dilakukan selama 21 kali saat pasang purnama selama periode antara tanggal 20 April 1999 sampai 18 April 2000. Dengan mengacu pada jarak waktu sampling, penelitian ini terbagi atas 2 bagian: (1) antara 20 April – 22 November 1999, pengambilan contoh dilakukan setiap 2 minggu sekali, dan (2) antara 22 Desember 1999 – 18 April 2000, pengambilan contoh dilakukan satu bulan sekali. Pengumpulan spesimen dilakukan dengan bantuan alat '*yabby pumps*' pada saat air surut. Contoh yang terkumpul selama penelitian terdiri atas 5 628 betina, 4 385 jantan, dan 346 individu tak teridentifikasi jenis kelaminnya, sehingga nisbah kelamin secara keseluruhan bias ke betina. Namun demikian, dengan membagi populasi ke dalam beberapa kelas ukuran, ada pola nisbah kelamin yang terlihat, dan pola ini nampaknya berkaitan dengan aspek biologi reproduksi udang tersebut.

Kata kunci: nisbah kelamin, udang lumpur, thalassinidea, callianassidae, *Nihonotrypaea japonica,* Ariake Sound.

INTRODUCTION

Callianassid ghost shrimps are one of the most conspicuous members of the littoral and sublittoral large-sized benthic animals burrowing in sediments worldwide. These organisms reside in complex tubular branching burrows for shelter, reproduction and feeding. During burrow construction or maintenance and feeding (commonly deposit feeding), unwanted sediment is ejected from the burrow, forming mounds on substratum surface. This activity is one of so-called bioturbation activities that are conducted by many burrowing fauna.

On intertidal sandflats of the Ariake-Sound estuarine system in western Kyushu, Japan, *Nihonotrypaea japonica* and *N. harmandi* are the most common members of the family Callianassidae. The two congeneric species co-

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occur on some of the sandflats (see Fig. 8 in Tamaki *et al*, 1999). Some bioecological information on the two species has been published (e.g. Tamaki *et al* (1997); Tamaki and Ueno, 1998; Miyabe *et al* (1998); Tamaki *et al*, 1999; Tamaki and Miyabe (2000); Wardiatno and Tamaki, 2001; Wardiatno *et al*, 2003), but none of them discussed about sex ratio specifically. The aim of the present study is to discuss the sex ratio in the population of *N. japonica* from biological point of view with highlighting on reproduction aspect.

MATERIALS AND METHODS

The present study was carried out on an intertidal sandflat developed at the mouth of Shirakawa River, central part of Ariake Sound, western Kyushu, Japan (see Transect *J* in Figs. 1 and 2 of Wardiatno *et al*, 2003). At extreme low spring tides the sandflat is exposed for more than 2 km seaward. *Nihonotrypaea japonica* occurs over almost the entire sand flat. The sediments were moderately sorted medium to fine sands, with the 0.9 - 8.5% silt-clay content. The depth of the sediment column was at least 76 cm, and could probably reach more than 1.5 meter.

Subsurface temperatures followed a predictable pattern with a yearly range of almost 23°C with the lowest value of minimum temperature occurring in January and the highest value of maximum temperature in September. The minimum temperatures remained below 15°C from December to April. Subsurface salinity also showed variation throughout the year with values varying from 18-30 *psu*. The highest value was recorded in May (30 *psu*), but most of the time salinity values were rather constant in the range of 25-27 *psu*. The lowest values were recorded on July and September, reflecting higher precipitation just before and/or during the months. Subsurface oxygen concentration was less than 1 *mg/l* on most of time. In the wintertime the level increased up to 2.5 *mg/l*, indicating a lower consumption by microorganisms due to lower temperatures.

Sampling of the *Nihonotrypaea japonica* population was conducted on a total of 21 occasions (spring tides) during the period from 20 April 1999 to 18 April 2000. With regards to the sampling interval, the study period can be grouped into 2 parts: (1) during 20 April – 22 November 1999, every 2 weeks, and (2) during 22 December 1999 – 18 April 2000, once a month. Sample collections were made by means of 'yabby pumps' during low tide on each occasion at 4 stations (Stn-1 – Stn-4) placed along a permanent transect which extended perpendicularly from the shoreline. The distance of Stn-1, Stn-2, Stn-3 and Stn-4 from the shoreline was 244 m, 644 m, 1064 m and 1464 m, respectively. At least 100 specimens were collected from each station on each occasion, yielding a variation in total collection on each occasion from 411 to 666. All specimens were immediately preserved in 10% buffered seawater-Formalin.

The following parameters were determined: (1) sex [according to the presence (in females) or absence (in males) of the second pair of pleopods, unless evident by the conspicuous presence of ovaries in females], and (2) total length [abbreviated as TL (=length along mid-dorsal curvature from tip of rostrum to posterior margin of telson)]. No determination of sex was made for shrimps smaller than 10-mm TL size, but these specimens were allocated equally to both sexes. This is because the additional small-sizes (< 24 mm-TL) specimen collections made on 13, 27 and 28 March 2001 showed that the ratio of male to female was nearer unity (331 female: 333 male; $?^2 = 0.001$, $p > 0.05$).

Size (TL)-frequency of total samples for both sexes was plotted using 4 mm intervals of total length. Sex ratio of the entire populations and each of size classes were analyzed using chi-squared tests with a correction called Yates' Correction for Continuity (Fowler and Cohen 1990) to determine significant deviations from an expected 1:1 sex ratio.

RESULTS

In the present study the total number of shrimps collected were 10 359. The size (TL)-frequency histogram of all shrimps collected between 20 April 1999 and 18 April 2000 is presented in Fig. 1. Males show a more symmetrical distribution, but the average size of females (48.2-mm TL) was highly significantly larger than that of males (43.4-mm TL) ($p < 0.001$; *z*-test for comparing the means of two large samples as in Fowler and Cohen, 1990).

However the largest female (74.6-mm TL) was smaller than the largest male (79.5-mm TL). The minimum size of female with developed ovary and ovigerous female was 23.6 mm-TL and 32.4-mm TL, respectively.

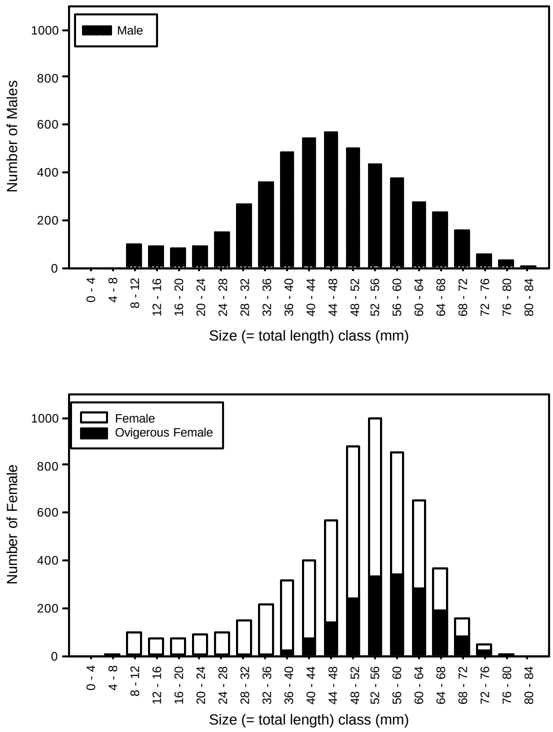

Figure 1. Size (TL)-frequency Distributions of Male and Female *Nihonotrypaea japonica* of the Pooled Samples Collected Between 20 April 1000 and 18 April 2000.

The collected samples consist of 5628 females, 4 385 males, and 346 sex-unidentified individuals, giving a female-biased sex ratio for the entire population (male:female= 0.78, ?^{2} = 152.29, p < 0.05). Considering the size classes (Fig. 2), the number of males and females belonging to each size was not statistically different up to 24-mm TL. At larger size (up to 36-mm TL) there was a clear and systematic drop in female numbers, producing highly male-biased sex ratios. Beyond the size of 36-mm TL, the number of males declined, bringing about nearly equal to a 1:1 sex ratio at size 44-mm TL. The number of males continued to decrease to produce female-biased sex ratios at 48 to 68-mm TL. As females die earlier than males (Wardiatno and Tamaki, unpublished data), the sex ratio became closer to 1 value at larger size class. Exceeding 76-mm TL, males predominated the population.

DISCUSSION

The subject of sex ratio has been part of thalassinidean studies during four decades (Hailstone and Stephenson 1961; Devine 1966; Forbes 1977; Dworschak 1988, 1998; Felder and Lovett 1989; Witbaard and Duineveld 1989; Rowden and Jones 1994; Dumbauld *et al.* 1996; Tamaki *et al.* 1997; Berkenbusch and Rowden 1998, 2000; Nates and Felder 1998; Shimizu and Rodrigues 1998; de Souza 1998; Pezzuto 1998; Feldman *et al.* 2000), but many of them was based on smaller numbers of specimens comparing to the present study, except Tamaki *et al.* (1997). Though statistical tests could be performed with any number of data, the use of few data might produce equivocal results.

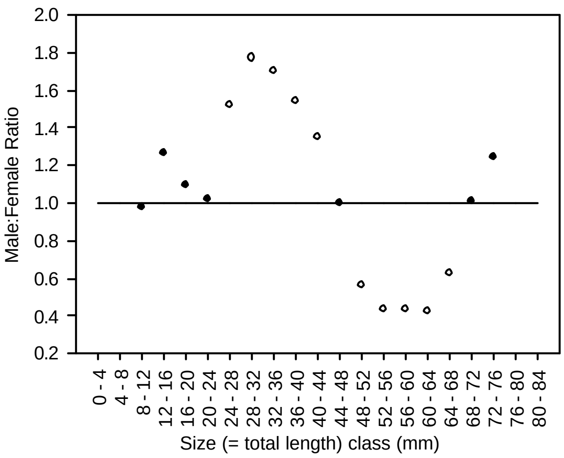

Figure 2. Sex Ratio (males:females) of *Nihonotrypaea japonica* at Each Size Class in Pooled Samples Collected Between 20 April 1999 and 18 April 2000. Open Circles Indicate Sex Ratios Significantly Different from 1:1 (p=0.05, ?^{2} Test with Yates Correction for Continuity, *see* Fowler and Colen, 1990). The Solid Line is the Line for 1:1 Ratio.

Like most thalassinids, the sex ratio for the entire population of *Nihonotrypaea japonica* was 1:0.78 in favor of females and was close to 1:1 in juveniles (< 24-mm TL). However, variations in the ratios by size classes were detected (see Fig. 2) (see further discussion below). Unusual male-biased ratios for the whole population were found in *Callianassa kraussi* (see Forbes, 1977), *C. subterranea* (see Rowden and Jones, 1994) and *C. tyrrhena* (see Dworschak, 1998). Un-biased sex ratio was recorded in *Callianassa filholi* (Berkenbusch and Rowden, 2000).

Records of female-biased sex ratio in callianassids population as an artifact of collecting methods (*i.e.* 'yubby-pumps' may selectively sample the generally lighter females, while corers may also omit the possibility for catching deeper burrowing males) were hypothesized by Rowden and Jones (1994). In the present study, four of twenty-one sampling occasions showed that the number of males were higher than that of females. Moreover by considering the size classes, some of them showed male-biased ratio. So, their hypothesis seems to be failed. In addition, Pezzuto (1998) reviewed that female-biased patterns have been found in species living in various environments, and have been sampled with various gears/methods.

In the present study, females started to develop their ovary beyond 24-mm TL, as indicated by the smallest female size (23.6-mm TL) with developed ovary. From this size to maturation size (32.5-mm TL: Wardiatno and Tamaki, unpublished data), females allocate their energy for reproduction more than males do, which may lead to a higher mortality, and this creates male-biased sex ratio.

Relative densities of females on size between 20-mm and 32-mm TL (Mean ± SD = 17.7±11.3 individuals) were significantly lower than those of males (Mean ± SD = 31.5±19.5 individuals) during the study period (*t*-test; $p < 0.001$), indicating a higher rates in mortality for females. After becoming matured, the males have to fight for mating partners (I suppose that they become matured at = 32.5-mm TL). So, the number of males after maturation decreased gradually, yielding female-biased ratios in some larger classes.

Combatant behaviour has been proved to cause serious injuries or even death of one or both opponents in *Neaxius vivesi* (see Berrill, 1975). Such behaviour also characterized *Callianassa filholi* (see Devine, 1966), *Trypaea australiensis* (see Hailstone, 1962), *C. tyrrhena* (see Ott *et al.*, 1976: as *C. stebbingi*), *C. subterranea* (see Rowden and Jones, 1994), *Lepidophthalmus louisianensis* (see Felder and Lovett, 1989), *Neotrypaea californiensis* (see Bird, 1982), *Sergio mirim* (see Pezutto, 1998) and *Nihonotrypaea harmandi* (see Tamaki *et al.*, 1997). Though no observation of fighting was made, the apparent difference in major chela between larger-sized males and females indicated *N. japonica* to have antagonistic behaveour, as firstly suggested by Felder and Lovett (1989). However, a reduced number of sexually mature males through fights and/or due to predation when they leave the burrow to search for females, could have advantages for the population: (1) as natural selection to get the 'best' specimens, (2) enhancing the probability of each surviving males to discover females by excavating randomly in every direction, and (3) as an alternative strategy to overcome the problem of locating mating partners below the sediment surface, without selecting strategies often used by other benthic animals (Pezzuto, 1998). In other words, antagonistic behavior probably plays a role in the regulation of population density as suggested for *Upogebia deltaura* by Tunberg (1986).

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