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Spatial distribution and recruitment of pelagic larvae of sand bubbler crab, *Scopimera globosa**

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Abstract: *Scopimera globosa* burrows its nest into the sand beach of upper littoral zone. The larval migratory process seems to be influenced by both hydrographical conditions and spatial distribution pattern of larvae. The surveys were carried out at fixed time intervals (daily to biweekly) in Tomioka Bay in the summer of both 1980 and 1981. Samples were collected by a Kitahara-type plankton net with NGG 54 cloth and hand-made sledge net with the same cloth.

Pelagic larvae of all stages tended to be distributed in a particular area near the adult habitat. Their vertical distribution patterns also tended to be concentrated at the bottom layer. The larvae after stage III zoea strongly showed a concentration in their spatial distribution patterns. Their spatial distribution seems to be induced by not only the physical oceanographic conditions but also the compound effect of a larval responsive behavior to environmental conditions and water movement.

The zoeae and megalopae migrate between the sublittoral zone and the littoral zone (adult habitat) by riding on every tidal current. This migratory process has not yet been reported and is smaller in scale than the assumed migratory models. This process seems to be a peculiar characteristic of *Scopimera globosa* larvae.

1. Intruduction

The persistency of benthic population depends strongly on the process of larval recruitment. This process is influenced by both environmental condition and spatial distribution pattern of pelagic larvae. In brachyuran species, the larval distribution have been studied in three large bays of Japan (*Pinnixa rathbuni* in Ise and Sendai bays: SEKIGUCHI, 1979, 1981, 1983, 1988; SEKIGUCHI and ODATE, 1983; some brachyuran species in Tosa bay: YATSUZUKA and IWASAKI, 1980), in the pacific coastal region of North America (*Cancer magister*: LOUGH, 1976), and in Chesapeake Bay on the Atlantic coast (some brachyuran species: SANDIFER, 1973, 1975; DITTEL and EPIFANIO, 1982; EPIFANIO, 1987; EPIFANIO and DITTEL, 1982). They have revealed that there is specific difference in large scale horizontal distribution patterns of larvae.

MCCONAUGHA (1988) mentioned that the pelagic larvae of crustaceans belong to any of the following three patterns of distribution: 1) larvae retained within the estuary; 2) larvae advected to the adjacent continental shelf (20–30km offshore); and 3) larvae expelled and widely distributed across the shelf. EPIFANIO (1988) also reviewed the spatial distribution patterns and the responsive behavior of estuarine larvae and assumed four models of recruitment mechanism in the estuary and the shelf. As the surveys in their study were always conducted in a large bay or in an extensive coastal area, the models are assumed in a large scale and applied in the recruitment mechanism of the crustacean species with an extensive habitat. It will be, however, difficult to apply the same models to the sand bubbler crab, *Scopimera globosa*, inhabiting locally and in a very limited habitat. In this species, the larvae collected by a large scale sampling are not regarded as a concern in recruitment, but in dispersion and/or death migration. An attentive survey, therefore, has to be conducted

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in an area of small scale so as to elucidate the temporal and spatial distribution patterns of the larvae contributing to the recruitment.

In the present study, the spatial distribution pattern of *S. globosa* larvae is revealed by intensive survey. This study also discusses the larval migration and recruitment process in relation to tidal cycle.

2. Materials and Methods

The investigations were carried out in Tomioka Bay in the summer of both 1980 and 1981. The bay is a small semi-open sea region which is located on the northwest coast of Amakusa Shimoshima Island, western Kyushu. The *S. globosa* population inhabits only limited area of the upper beach (Fig. 1). The area is located in the innermost part of the sand flat called the Higashi Hama, and opens to the sea in the northern direction. The distance from Mean Low Water of Spring tides (MLWS) to the lower margin of *S. globosa* habitat is about 500m.

Plankton samplings in the crabs' habitat (Stn. A in Fig. 1) were nocturnally carried out at high water from June 24 to July 6, 1980. The samples were collected by a Kitahara-type plankton net with NGG 54 cloth towed horizontally for ten minutes. To elucidate the relationship between the occurrence of pelagic larvae and tidal rhythm, the plankton samplings were conducted at station B on August 29 and 30, 1980. The samplings were made at intervals of one hour at the surface, middle and bottom layers. The sampling for the spatial distribution of larvae were carried out weekly or biweekly from May to August, 1981 at stations 1 to 16 in Tomioka Bay. The samples were collected at the surface and bottom layers. On the sampling at the bottom layer of stations 1 to 16 and B, a hand-made sledge net based on Kitahara-type plankton net with NGG 54 cloth was used. A Kitahara-type plankton net was horizontally towed at the surface and middle layers. All nets were towed for 100m at all sampling stations.

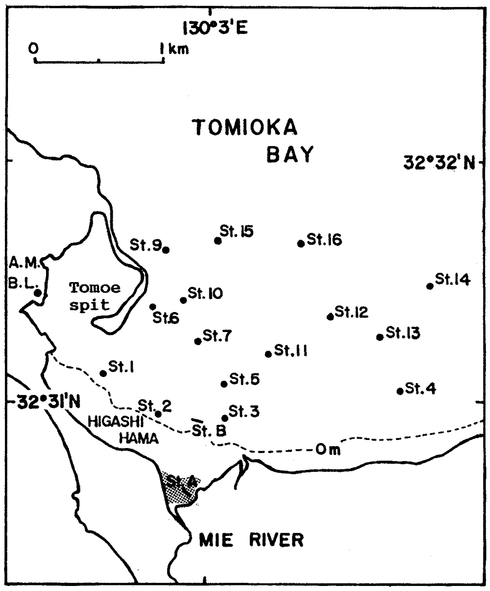

Fig. 1. The vicinity of study area, sampling stations and habitat of *Scopimera globosa* (shadow area) in Tomioka, western Kyushu.

All samples were preserved in 10% formalin-sea water for later sorting and counting. Samples were taken to the laboratory, scanned under a binocular microscope, and the larvae were removed. Developmental stages were determined by the number of natatory hairs. Staged individuals were counted and preserved in 70% alcohol.

The samples in 1980 were condensed into 100ml and their aliquot subsamples of 1ml were made with a pipette. The larvae contained in each subsample were counted three times and the total captured numbers were estimated. Individual larvae in all samples obtained in 1981 were counted.

3. Results

It was expected that the migratory patterns of pelagic larvae and their spatial distributions in the coastal region correlate each other. At first, the horizontal and vertical distribution patterns of each larval stage in the coastal region will be elucidated. Then the larval migration and recruitment will be examined on the basis of the distribution patterns.

Fig. 2 shows the changes of horizontal distribution patterns of *S. globosa* zoeae in Tomioka Bay from May 26 to August 4, 1981. Zoea larvae of stages I to III appeared in low densities from May to June (early

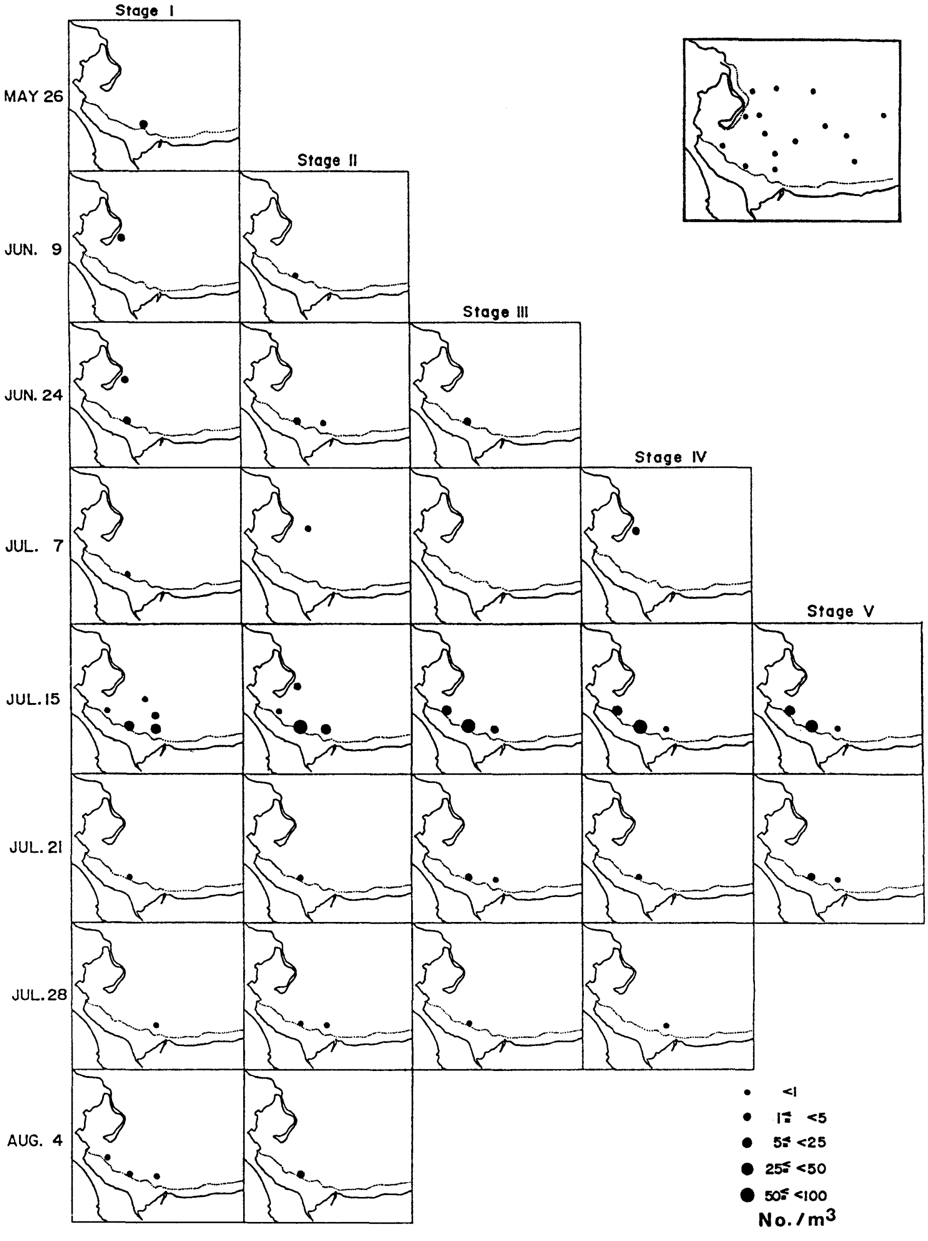

Fig. 2. Horizontal distributions of each zoeal stage of *Scopimera globosa*. The figure at upper right hand corner shows the sampling points.

reproductive season); and zoeae of all stages appeared abundantly in the middle of July.

The stage I zoeae were distributed at station 3 (nearest to the adult habitat) and at station 6 off Tomoe spit on the west of the bay from May 26 to June 24 during the early reproductive season. In the middle of July, though a few zoeae of stage I were distributed at stations 5 and 7 about 600m offshore, most of them were distributed at stations 1 to 3 located along MLWS line. The distribution patterns of zoeae after stage II showed similar tendency as that of stage I zoeae. Zoeae of stages II to IV were mainly distributed at stations 2 and 3 adjacent to the adult habitat; while the last stage(V)

Table 1. Appearance ratio of *Scopimera globosa* zoeal stages at each station.

Stations	1	2	3	4	5	6	7	9	10	11	12	13	14	15	16
Stage 1	2.8	64.1	20.3		2.7	8.9	1.2								
2	0.6	83.6	13.7			1.2			0.9						
3	5.4	90.0	4.6												
4	6.7	91.1	1.0			1.2									
5	14.1	84.5	1.4												

zoeae were distributed only at stations 1 to 3 during the survey period.

According to the variations in appearance ratio of all stages at the stations (Table 1), the zoeae of stages I and II were distributed more extensively than those of the other stages. Stages I zoeae appeared at six stations (1, 2, 3, 5, 6, and 7) and the stage II at five stations (1, 2, 3, 6, and 10). The appearance ratio of stage I zoeae at stations 5, 6, and 7 were 2.7%, 8.9%, and 1.2%, respectively. These stations were located away from the adult habitat. The appearance ratio of stage II zoeae were also very low at two offshore stations (1.2% at station 6 and 0.9% at station 10). On the contrary, at stations 2 and 3, which were located along MLWS line, the appearance ratio of stages I and II zoeae were in the high range from 84.4% to 97.3%. The ratio of stage I zoeae were 64.1% at station 2 and 20.3% at station 3; and those of stage II were 83.6% at station 2 and 13.7% at station 3.

Most zoeae after stage III were distributed at stations 1, 2, and 3 along MLWS line. The especially high appearance ratio at station 2 of stages III, IV, and V were 90.0%, 91.1%, and 84.5%, respectively. The pelagic larvae of *S. globosa* were thus distributed intensively in the region neighboring the sand beach, although the distribution range of the early stage zoea was relatively extensive. The main distribution region of larvae did not shift horizontally with the development of larvae.

The vertical distribution patterns of each zoeal stage were expressed as the appearance ratio at each layer (Table 2). The stage I zoeae were distributed at the surface layer with the appearance ratio of 11.8% and at the bottom layer with 88.2%. More than 96.0% of the zoeae after stage II, however, appeared at the bottom layer, and the ratio was higher as the stage of larva developed. As this result was obtained in the day time, there was still a problem on the diurnal changes in the vertical distributions for each larval stage.

Table 2. Appearance ratio of *Scopimera globosa* zoeal stages at each layer.

Stages	1	2	3	4	5
Surface Layer	11.8	3.6	3.1	0.7	0.8
Bottom Layer	88.2	96.4	96.9	99.3	99.2

The hourly changes of appearance of each larval stage were, therefore, examined at station B (Fig. 3). Station B was located between stations 2 and 3 where the zoeae of all stages appeared abundantly. Stage I zoeae were collected plentifully at the bottom layer from low tide to flood tide (from 18:00 to 19:00 in August 29; from 5:00 to 9:00 in August 30). While, from high tide to ebb tide (from 23:00 in August 29 to 4:00 in August 30; from 10:00 to 14:00 in August 30), stage I zoeae appeared at all layers in almost equal number.

The zoeae after stage II appeared more abundantly at the middle and bottom layers. Compared with stage I zoea, they were more abundant at bottom layer in both flood and ebb tides. The zoeae appeared more frequently at the bottom layer as the larva developed to more advanced stage. The *S. globosa* larvae of all stages were

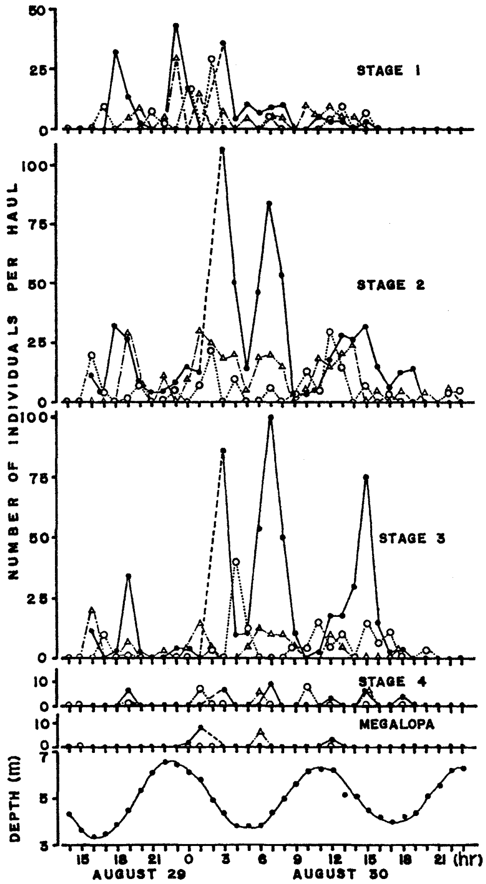

Fig. 3. Hourly changes of individual appearance of *Scopimera globosa* larvae at station B from August 29 to 30 in 1980. The open circles, open triangles and closed circles show the surface, middle and bottom layers, respectively.

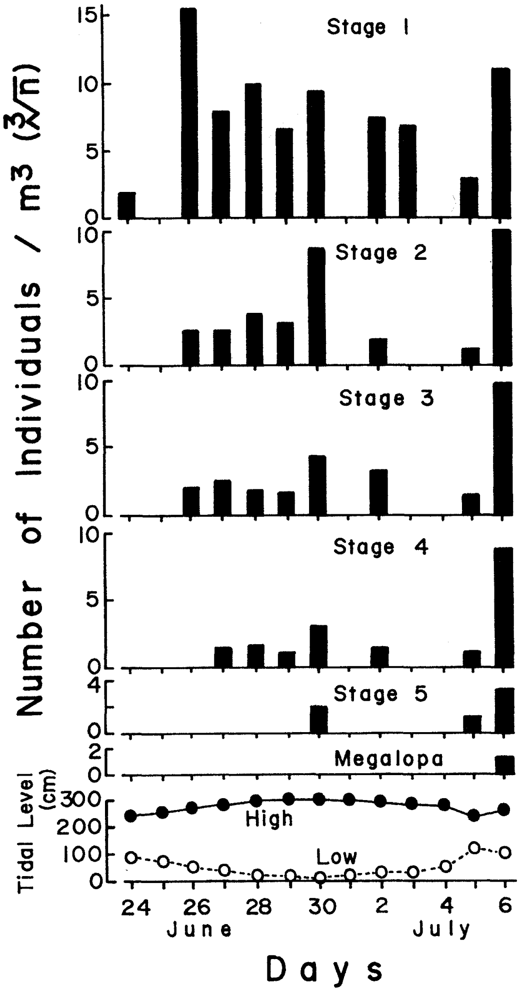

Fig. 4. Diurnal changes of individual appearance of *Scopimera globosa* larvae at station A from June 24 to July 6 in 1980.

distributed in large number at the bottom layer, not only in the day time but also in the night time.

According to the daily samplings carried out at nocturnal high tide from June 24 to July 6 in 1980, the density of stage I zoeae reached the first maximum at quarter moon, three or four days before the spring tide (Fig. 4). The density then were gradually reduced and increased again at neap tide. This continuous sampling also revealed that all larvae after stage II zoea appeared occasionally and became abundant on both June 30 and July 6.

These results indicate that appearances of these larvae are irregular without the apparent influence of semi-lunar cycle. This also demonstrates that the pelagic larvae of *S. globosa* as they develop always migrate in relation to tidal current between the sublittoral and the littoral zones, where the adult crabs inhabit.

4. Discussion

The distribution pattern of pelagic larvae is known to play an important role in the recruitment of larvae and in the persistence of adult population (BURTON and FELDMAN, 1982; CRONIN, 1982; EPIFANIO and DITTEL, 1982; EPIFANIO, 1988; FORBES and HAY, 1988).

SANDIFER (1973, 1975) had surveyed Chesapeake Bay and emphasized that the distribution pattern of larvae was nearly related to the adult habitat; larvae of the species which were heavily dependent on estuarine habitats tended to be abundantly retained within the estuary; and those of the species which were not restricted to estuarine habitats tended to be dispersed to the open sea. In Ise and Mikawa Bays the *Pinnixa rathbuni* larvae released in the adult habitat were rapidly transported in a counterclockwise circulation toward the opposite side of the habitat where they formed a belt-shaped distribution (SEKIGUCHI, 1979, 1981, 1983, 1988). After at least one month the larvae moved and were recruited to the adult population. He also suggested that the distribution pattern and recruitment process of larvae were influenced by residual flow and seasonal winds.

The present study demonstrated that pelagic larvae of *S. globosa* were abundant in the region horizontally along MLWS line; and those of all stages were mainly distributed in the bottom layer. On the bottom current system of Tomioka Bay, there is a current curtain on the north of the bay and the waters of the bottom layer constantly flow landward in the region along MLWS line (SUZUKI et al., 1982). These oceanographical conditions indicate the possibility of larvae being passively accumulated by the current curtain and the landward flows. The similar pattern of spatial distribution is, however, not always observed in the larvae of all decapod species appearing in Tomioka Bay (unpublished). The larvae of *S. globosa*, therefore, seem to remain actively within the region near MLWS line. The spatial distribution pattern of *S. globosa* larvae seems to be determined by not only the physical oceanographic factors, such as waves and water current, but also the combination of the scale and location of adult habitat and larval behavior. The spatial distribution is also considered as a species-specific characteristic.

The region, where *S. globosa* larvae remained, is located at only 500m from the habitat of adult crabs, and probably in the lower part of surf zone. It has been reported that the surf zone is an important area for fish larvae; and abundant fish larvae exist in this zone and its adjacent waters (SENTA and KINOSHITA, 1985; BENNETT, 1989). The region near MLWS line also seems to play a role as nursery area and to supply sufficient amount of food (phytoplankton, zooplankton, and detritus) for *S. globosa* larvae, although the existence of abundant fish larvae may give a risk of predation.

Most models of the previous studies (EPIFANIO, 1988; MCCONAUGHA, 1988) assume that the larvae migrate to the adult habitat first during late pelagic or post-larval stage. In *S. globosa*, zoeal and megalopal larvae always migrate between the littoral zone and the sublittoral zone by riding on the tidal current. This migratory process is first reported by the present study, and is smaller in scale than the previous models. The retention and migration of all larval stages seem to be necessary for *S. globosa* inhabiting littoral zone in order to recruit benthic population.

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コメツキガニ *Scopimera globosa* 浮遊幼生の分布と回帰

鈴 木 廣 志 ・ 菊 池 泰 二

要旨: 砂質干潟に穴居するコメツキガニの浮遊幼生の分布と回帰過程を明らかにする目的で、1980年および1981年の夏季に西九州天草下島の富岡湾において調査を行った。

コメツキガニの浮遊幼生は、水平分布では全令期にわたり成体生息地に近い大潮平均低潮線（MLWS）付近に最も多く分布した。垂直分布では、第1令および第2令ゾエア幼生では、底層への分布の偏りは若干弱いが、第3令ゾエア期以降になるとほとんどの個体が底層に分布する傾向を示した。これら水平、垂直分布様式は幼生の発育に伴って大きく変化することはなかった。富岡湾に出現した全ての幼生が、必ずしもコメツキガニ幼生と同じ分布様式を示さなかったことから、本種幼生のMLWS付近における集中化は、物理的にのみ起きているのではなく、塩分や光量等に対する幼生の反応習性の違いと水塊移動の複合結果として考えられる。また、コメツキガニ各令期のゾエア幼生は、毎日の潮汐流に乗り沿岸域と成体生息地の潮間帯域を、行き来していることが明らかになった。このような移動は、従来の幼生研究で想定されていた規模よりはるかに小さく、また未だ報告されていない特徴と考えられる。