Bull. Fac. Fish., Mie Univ.
No. 8 : 19—29
October 1, 1981

Distribution of Larvae of *Pinnixa rathbuni* SAKAI (Decapoda: Pinnotheridae) in Ise Bay and its Neighbouring Coastal Waters, Central Japan-II

Larval Aggregations, with Notes on their Dispersal Properties.

Hideo SEKIGUCHI
Faculty of Fisheries, Mie University

In deducing that abundant benthic populations of *Pinnixa rathbuni* have been always found in western parts of Ise Bay, it was thought that early larvae would appear first in the western parts of the bay. But past observations showed they were always found abundantly first in the eastern parts of the bay. So there remained to be inquired into the question why they occurred abundantly not in the west but in the eastern parts of the bay. Thus, it is necessary to know in detail the properties of aggregations of the larvae found in the eastern parts of the bay.

This paper deals with investigating a small-scale distribution of the larvae in the eastern parts of the bay where numerous larvae, at early stages, appear.

Zoea 1-5 larvae were found abundantly in a very narrow belt-shaped zone along the coast of Tita Peninsula, though the centre of their distribution was localized just off "Utumi" and "Yamami". Patterns of the small-scale spatial distribution were almost the same through the zoeal stages. This indicates that dispersal would not be considerable through the zoeal larvae. Aggregated masses for zoea 1-4 stages, which were observed close to the coast of "Utumi" and "Yamami", showed an almost clear-cut margin and thus a trapezoid-shaped distribution, because the numbers of the larvae caught changed drastically in directions both toward the off-shore water and along the coasts of Tita Peninsula. Distributional features of the larvae indicated that dispersal of the larvae, forming the belt-shaped zone of aggregations along the coast of Tita Peninsula, would be strengthened only in the southern area along the coast, being negligible in the northern area. Characteristic water movements underlie the forming of the belt-shaped aggregations along the coast. However, aggregations of larvae must be caused by the larvae themselves, hydrographical and other biological features are not responsible for forming this much aggregated distribution. This is clearly understood by comparison with those copepod collected simultaneously. Aggregations of early larvae, found in the eastern part of Ise Bay, would be correlated with the presence of aggregated benthic adults, though we have not yet evidence for the presence of this hypothesized benthic population.

Keywords : *Pinnixa*

The temporal and spatial distribution of *Pinnixa rathbuni* larvae were previously clarified in Ise Bay and its neighbouring coastal waters (SEKIGUCHI 1977, 1979); the larvae were abundantly found only in Ise Bay from November to March of the following year, and the temporal variation of their distribution showed a clockwise movement in Ise Bay without considerable loss of the larvae into the open coastal waters. While the zoeal larvae abundantly appeared mainly from November to December, their distribution was extremely restricted to the eastern part of Ise Bay as indicated in Fig. 1. In deducing that abundant benthic populations of *Pinnixa rathbuni* have been always found in the western part of Ise Bay (MIYADI 1941; KITAMORI et al. 1970) it was assumed that early larvae of *Pinnixa rathbuni* would appear first in the western part of the bay. But past observations, as cited above, showed that they were always found abundantly first in the eastern part of the bay. So there remained to be inquired into the question why they occurred abundantly not in the west but in the eastern part of the bay. Before going on to the problem stated above, it is necessary

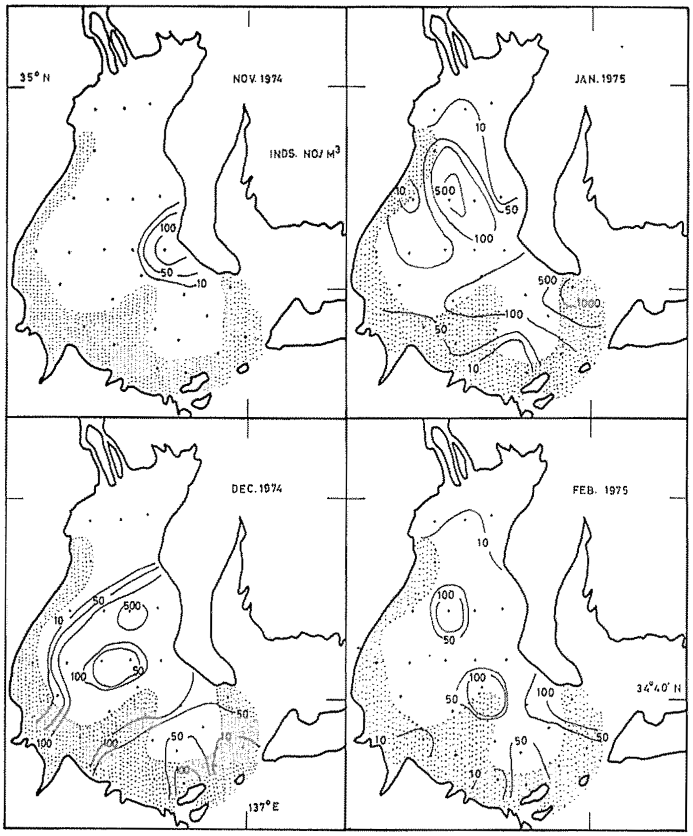

Fig. 1. Spatial distribution of the larvae of *Pinnixa rathbuni* from Ise Bay. Dotted area indicates spatial distribution of benthic stages of *P. rathbuni* elucidated by Miyadi (1941).

to know in detail the properties of aggregations of the zoeal larvae found in the eastern part of the bay so that we will be able to place a concrete basis for studying the mechanisms by which the larval populations would be maintained within the bay without the loss into the open coastal waters.

This paper deals with investigating a small-scale distribution of the larvae of *Pinnixa rathbuni* in the eastern part of Ise Bay where numerous larvae at early stages appear. The author wishes to thank the members of Owari Branch of Aichi Prefectural Fisheries Research Laboratory for facilitating their laboratory. Thanks are due to Dr. H. IWASAKI and his staff for their encouragement concerning this study. This study was supported by a grant authorized by the Mie Prefectural government.

Studying Area and Materials

In order to study a small-scale distribution of the larvae of *Pinnixa rathbuni*, we set eight lines for sampling the larvae by means of a plankton net near the western part of Tita Pininsula (e.g., the eastern part of Ise Bay) (Fig. 2). The distance between sampling stations on each line was nearly one kilometer. Investigaton was carried out on December 1-2 1980, because the early larvae can be found abundantly

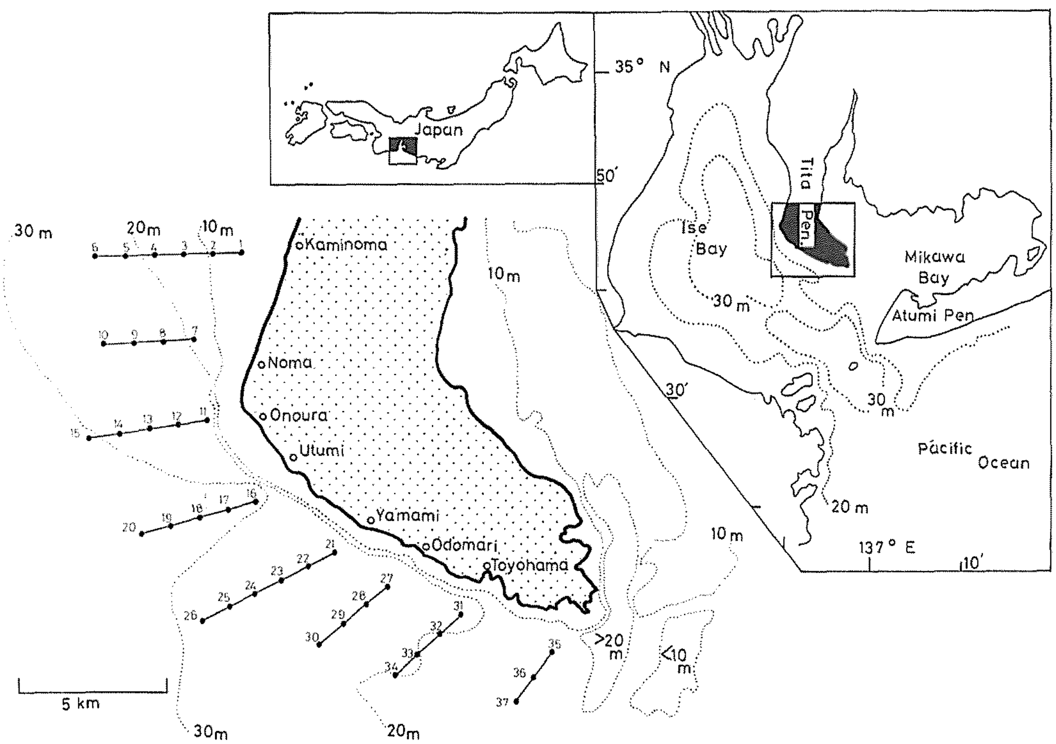

Fig. 2. Studying area and sampling stations.

in the eastern part of Ise Bay every December recalling past investigations (Fig. 1; SEKIGUCHI 1977, 1979). Plankton nets (0.33 mm mesh-openings, 23 cm in diameter) were vertically hauled from bottom to surface at each station in the daytime. A total of 37 stations were covered by a small boat for two days.

Specimens of the larvae of *Pinnixa rathbuni* were sorted into the five zceal and one megalopic stages according to the larval features described by SEKIGUCHI (1978) so that it was possible to make distributional maps for each larval stage.

A zooplankton net employed in this study is not an ideal instrument for collecting crab larvae since a degree of net avoidance certainly occurs, and for this reason data has not been transformed to numbers per standard volume. So numbers per net haul have been used to show and/or track the dispersal of the "meroplanktonic" larvae released from the benthic populations of the *Pinnixa* crab.

Results and Discussion

Abundance and stage composition of *Pinnixa rathbuni* larvae, collected in the present study, is illustrated in Fig. 3. Zoea 3 larvae were found most abundantly, while few zoea 5 and megalopic stages were found. Relative abundance of each larval stage was almost similar to that obtained every December for the past investigations (SEKIGUCHI 1979).

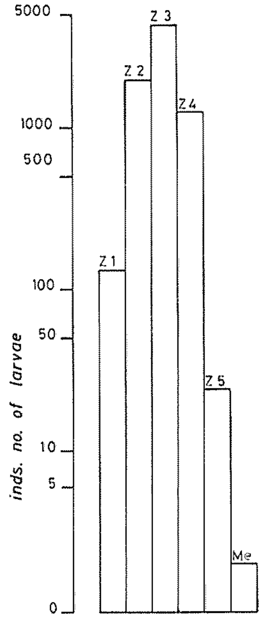

Fig. 3. Abundance of zoeal and megalopic stages of *Pinnixa rathbuni* collected in present study.
Z; zoeal stages, M; megalopic stage

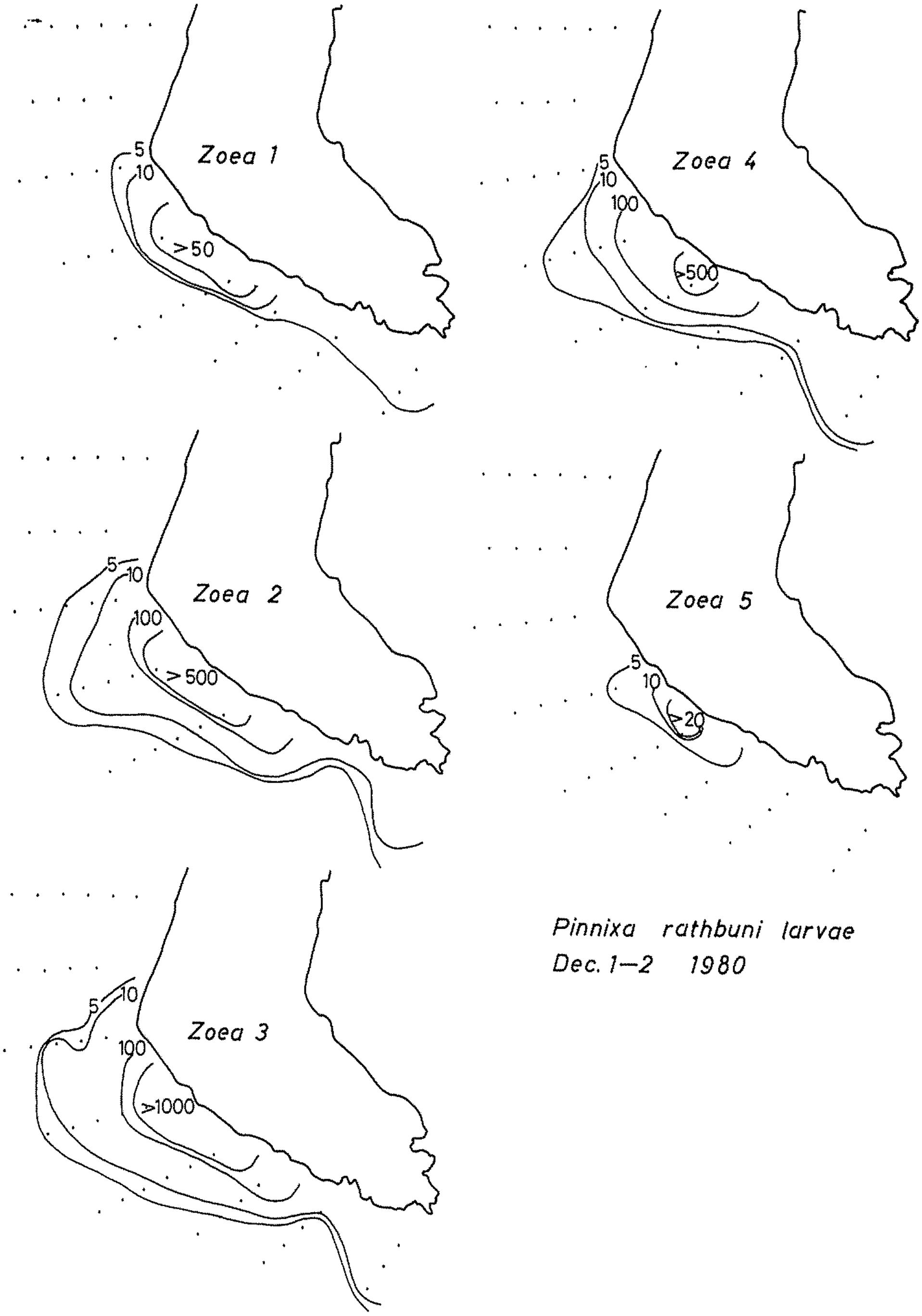

Fig. 4. Small-scale spatial distribution of the larvae of *Pinnixa rathbuni*. Numbers indicate those per net haul of *Pinnixa rathbuni*.

Spatial distributions of zoea 1–5 larvae are shown in Fig. 4 . Zoea 1–5 larvae were found abundantly in a very narrow belt-shaped zone along the coast of Tita Peninsula, though the centre of their distribution was also localized just off "Utumi" and "Yamami"; they appeared in the centre with the numbers of 73 (stn. 16)–95(stn. 21) ind./net haul for zoea 1 larvae, 737 (stn. 21)–882 (stn. 16) ind./net haul for zoea 2, 1525 (stn. 16) –2163 (stn. 21) ind./net haul for zoea 3, 219 (stn. 16)–746 (stn. 21) ind./net haul for zoea 4, and 6 (stn. 16)– 20 (stn. 21) ind./net haul for zoea 5. Two specimens of the megalopic stage were caught only at stn. 35 off "Yamami." The pattern of the small-scale spatial distribution was almost the same through the zoeal stages except zoea 5 larvae which appeared only at the stations off "Utumi" and "Yamami." This indicates that dispersal would be not considerable through the zoeal larvae.

Aggregated masses for zoea 1–4 stages, which were observed close to the coast of

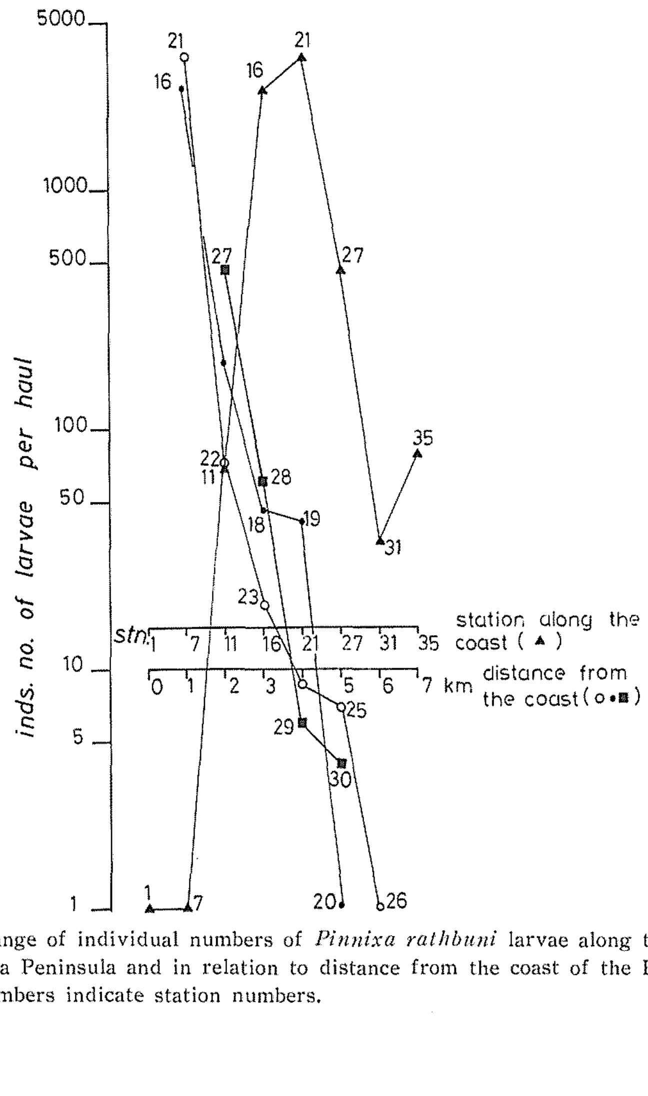

Fig. 5-a. Change of individual numbers of *Pinnixa rathbuni* larvae along the coast of Tita Peninsula and in relation to distance from the coast of the Peninsula. Numbers indicate station numbers.

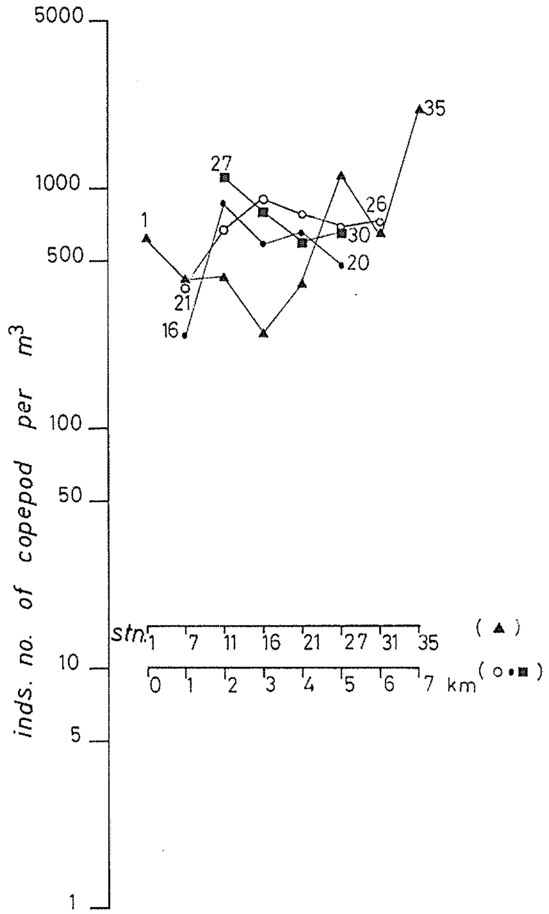

Fig. 5-b. Change of individual numbers of copepods along the coast of Tita Peninsula and in relation to distance from the coast of the Peninsula. Numbers indicate station numbers.

"Utumi" and "Yamami", showed an almost clear-cut margin, and thus trapezoid-shaped distribution, because the numbers of the larvae caught changed drastically in directions both toward the off-shore water and along the coast of Tita Peninsula (Fig. 5). Toward the off-shore water from the coast, they decreased drastically from more than 2700 ind./net haul around the centre down to nearly 100 ind./net haul at one kilometer away. From the north to the southern area along the coast of Tita Peninsula, they increased dramatically from zero up to 2705 (stn. 16)–3760 (stn. 21) ind./net haul, and then decreased down to 81 (stn. 35) ind./net haul. Deducing from the belt- shaped aggregations along the coast of Tita Peninsula, the larvae tend to disperse strongly along the coast, dispersal being negligible toward the off-shore water. Larval dispersal along the coast is also made clear by a change of larval composition along the coast (Fig. 6); apart from a few zoea 5 larvae, zoea 4 larvae became dominant from the centre of their

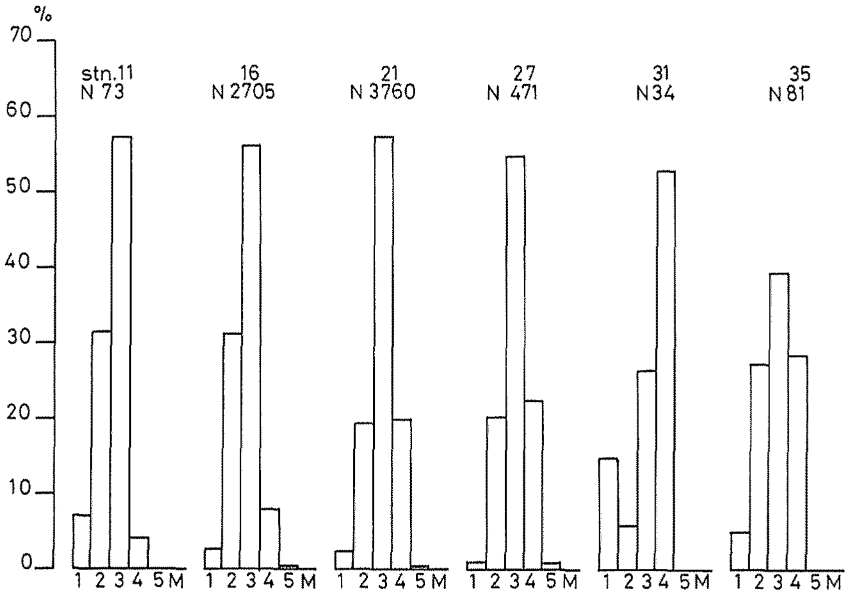

Fig. 6. Change of composition of *Pinnixa rathbuni* larvae along the coast of Tita Peninsula. N; individual numbers of the larvae collected at each station.

distribution to the southern area along the coast. Furthermore, Figs. 4 and 5 indicate that dispersal of the larvae, forming the belt-shaped aggregations along the coast, would be strengthened only in a southerly direction along the coast, being negligible in a northerly direction. Characteristic water movement underlies the forming of the belt-shaped aggregations along the coast. Strong tidal water moves mainly along the coast, and then the larval dispersal in a southerly direction along the coast, not in a northerly one, would be understood by the residual flow which may run in southerly direction along the coast. However, aggregations of the larvae must be caused by the larvae themselves, hydrographical and other biological features are not responsible for forming of this much aggregated distribution. This is clearly understood by comparison of the larval numbers with those of copepod numbers collected simultaneously (Fig. 5); copepod numbers tended to vary inversely with the larval numbers. This point will be discussed later. We believe that maintenance of the belt-shaped aggregated masses become possible due to biological mechanisms, for example diel change of vertical distribution in relation to ontogeny, preventing the larvae from dispersing considerably through the residual flow along the coast of Tita Peninsula, though this reason does not become apparent immediately.

Aggregations of early larvae, generally speaking, would be correlated with the presence of aggregated benthic adults, while the converse is not necessary true. Deducing from that mass aggregations were sometimes observed for the benthic populations of

Pinnixa rathbuni from Ise Bay (central Japan) as well as from Sendai Bay (northern Japan) (MIYADI 1941; YAMAMOTO *et al.* 1971, 1972), we ought to assume that early larvae released by the much aggregated abults would occur in aggregations. In fact, there are aggregations of the early larvae which have been already reported by SEKIGUCHI (1979) and have been shown in Fig. 1 .

The spatial distribution has been elucidated for the benthic populations of *Pinnixa rathbuni* from Ise Bay by MIYADI (1941), the result by whom are inserted into Fig. 1 of the present paper. With the recent progress of eutrophication, however, the habitat of the benthic populations of the *Pinnixa* crab have been severely uncomfortable due to depletion of a disolved oxygen content developing in the bay bottoms during the warm season. This situation would comfort an increase of the polychaetes there in parallel with a decrease of the *Pinnixa* crab (KITAMORI *et al.* 1970). Even in 1941, the year when Prof. Miyadi investigated for the benthic invertebrates from Ise Bay and then the habitat of the *Pinnixa* crab would expand mostly in the last forty years, aggregations of the benthic populations of the *Pinnixa* crab have not been found in the western part of Tita Peninsula (the eastern part of Ise Bay). Close inspection on sampling sites, which have been carried out in Ise Bay since MIYADI (1941), suggested that these investigations would not succeed in finding the benthic populations of the *Pinnixa* crab, if any, living close to the coast west of Tita Peninsula and, known to date in Ise Bay, would be not enough to understand the spatial distribution of the benthic populations of the *Pinnixa* crab, especially for those localized west of Tita Peninsula. In case of applying to the benthic populations of the *Pinnixa* crab from Ise Bay a peculiar behaviour such as mass migration of those from Sendai Bay (YAMAMOTO *et al.* 1972), the presence of this hypothesized benthic populations of the *Pinnixa* crab, which are localized along the coast of Tita Peninsula, may be in part due to moving to the shore-water west of Tita Peninsula shortly before releasing the larvae, though we have not direct evidence for the presence of this hypothesized population there.

Based on the facts elucidated in the present investigation, the early larvae which are restricted to the eastern part of Ise Bay and are extremely abundant there (SEKIGUCHI 1979) result from dispersing of the larval aggregations encountered with along the coast of Tita Peninsula. As referred previously, the temporal variation of larval distribution showed a clockwise movement in Ise Bay and distributional area becomes wide with the progress of ontogeny (see, Fig. 2 in SEKIGUCHI (1979)). Accordingly the main source of the larvae which maintain the larval populations in Ise Bay would be intimately related with the larvae greatly aggregating along the coast of Tita Peninsula. However, there remains a question as to whether the larvae sampled in the whole bay would come from the much aggregated early larvae in the shore-water west of Tita Peninsula, or not. The present study suggests that we had to cover extensively the shore- water areas for sampling the early larvae in order to know exactly the spatial distribution of the larvae in Ise Bay.

While pre- and mature individuals of some pinnotherid crabs, usually commensal with benthic invertebrates, take part in a presumably mating aggregation (quoted often as a copulatory swarm) in water from the coastal waters of Japan (SAKAI 1976), larval aggregations in water have been reported until recently only for two pinnotherids, *Pinnixa rathbuni* from Ise Bay as well as from Sendai Bay (SEKIGUCHI 1979; YAMAMOTO et al. 1972) and *Tritodynamia horvathi* from Tokyo Bay (pers. comm., S. NAGASAWA, Ocean Research Institute, University of Tokyo). As far as is known, there are no records on larval aggregations of brachyuran crabs, though galatheid crabs often form a extraordinary aggregation (termed as "lobster-krill") in surface water of the coastal regions of the world (LONGHURST 1967; KAWAMURA 1976). Different from lobster-krill observed often in coastal upwellings where the aggregations of galatheid crabs play a dominant role as only one intermediate stage along a food-chain (LONGHURST 1967b), little is known about the ecological role which the larval aggregations of pinnotherid crabs might play in plankton communities of the neritic and estuarine waters. The larval aggregations of *Pinnixa rathbuni* have no predators which would control their standing stock seriously in Ise Bay (SEKIGUCHI 1977), because they are furnished with long spines (SEKIGUCHI 1978). These aggregations would be "unuseful" animals in production made available by planktivorous fish which are heavily exploited and make the largest contribution to fish production in the bay. On the contrary, inferring from preliminary observation on gut contents of the *Pinnixa* larvae (except megalopic stage) which showed sometimes fragments of copepods, these larval aggregations would place a great impact on the abundance of planktonic copepods. As shown in Fig. 5, the abundance of the larvae varied inversely with that of copepods. Copepod numbers increased considerably toward the off-shore water from the coasts, e.g., the copepods showed a decrease in numbers only in the centre (stn.16 and 21) of the larval distribution, and a considerable difference in the copepod numbers was not found between the stations apart from the centre of larval aggregations. Also along the coast of Tita Peninsula, the copepod numbers tended to clearly decrease around the centre of the larval aggregations.

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