

Effects of a Grapsid Crab *Hemigrapsus penicillatus* on Colonizations of Small Animals in a Boulder Habitat

転石地の群集形成におけるケフサイソガニの役割

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Abstract

To clarify the roles of a grapsid crab *Hemigrapsus penicillatus* in the organization of macrobenthic communities of boulder habitats in a brackish Gamo Lagoon, we examined colonizations by small animals of two experimental boulder habitats with and without *Hemigrapsus* in a selected season (from Nov. 1993 to Dec. 1993). The results revealed that the presence of the crab increased the relative abundance of a free-living amphipod *Melita setiflagella* and decreased the species richness of small animals. Both the abundance of *Melita* and the total abundance of small animals did not significantly differ for the two habitats, although the presence of *Hemigrapsus* tended to increase the *Melita* abundance and to decrease the total abundance. On the other hand, the abundance of four tube-dwelling species (*Corophium uenoi*, *Grandidierella japonica*, *Neanthes japonica*, and *Pseudopolydora kempj japonica*) and two free-living species (*Jesogammarus hinumensis* and *Gnoriposphaeroma rayi*) were lower in the presence of *Hemigrapsus* than in its absence. In particular, the remarkable decreases of two abundant species, *Corophium* and *Grandidierella*, reflected the increase of the relative abundance of *Melita* in the presence of *Hemigrapsus*. The crab also influenced the accumulation of sediment into the experimental habitats: the sediment was more abundant in the absence of *Hemigrapsus* than in its presence. Five rare species (*Dimorphostylis* sp., *Pseudopolydora kempj japonica*, *Prionospio japonicus*, *Heteromastus filiformis*, and *Nuttallia olivacea*) appeared only in the habitat without the crabs. The high species richness in the absence of *Hemigrapsus* was mainly due to the appearances of these species requiring sediment for their living site. These results and the previous laboratory study, in which susceptibilities of some small crustaceans to *Hemigrapsus* predation were investigated, indicated that the crab affected the community structure of the boulder habitat by reducing sediment and/or consuming such sluggish species as *Grandidierella* and *Corophium*.

Introduction

The ecological community, the assemblage of interacting species, is structured by the various

interrelationships linking the individual species. The relationships multiply with the increase in species richness of a community, and many of the linkages are subtle or ephemeral (Putman, 1994). Therefore, the community structure is an extremely complex entity. However, community ecologists have occasionally found out that a single species population determines and changes the whole community structure by such processes as predation (e.g., Paine, 1966; Menge *et al.*, 1994), bioturbation (e.g., Rhoads & Young, 1970; Wilson, 1981; Tamaki, 1984; Kikuchi & Mukai, 1994), and habitat creation (e.g., Mukai, 1990; Nishihira, 1992a; Matsumasa & Nishihira, 1994). It is important, therefore, to clarify if the community includes a species which has a community-wide influence and, if so, what process the species is involved in.

The aims of this study are to evaluate the importance and to clarify the role of a grapsid crab *Hemigrapsus penicillatus* in the organization of the community developing on the boulder habitat in the brackish Gamo Lagoon in Sendai, Japan. The crab is a 'true estuarine species' widely distributed in estuaries in Japan (Ono, 1959; Goshima *et al.*, 1978; Ogura & Kishi, 1985; Fukui & Wada, 1986; Matsumasa & Kikuchi, 1993a), and is a relatively large-sized and abundant component of boulder habitats (Okamoto & Kurihara, 1989; Matsumasa & Shiraishi, 1993). The community of the boulder habitat in the Gamo Lagoon is characterized by its low species richness reflecting the general trend of estuarine ecosystems (e.g., McLusky, 1989). The life cycle and population structure of *Hemigrapsus* in this area was described by Okamoto & Kurihara (1987). In addition, the settlement seasons were also reported for some of the community's components such as an oyster *Crassostrea gigas* and barnacles *Balanus* spp. (Okamoto & Kurihara, 1989; Matsumasa, 1994). Therefore, experimental investigations can be easily designed. In the present study, the effect of the adult *Hemigrapsus* on the colonizations of boulder habitats by small animals was examined using an experimental habitat (the basket containing stones) in a selected season (from Nov., 1993 to Dec., 1993). The effects of the additional settlement of *Hemigrapsus* and of such sessile species as barnacles and oysters which change the habitat structure were separated from the intended effects in this study conducted in the selected season.

Materials and Methods

The field experiment was carried out in the channel of the brackish Gamo Lagoon in Sendai, Japan (38° 15' N : 141° 01' E). The environmental characteristics have been previously described (Matsumasa & Kurihara, 1988). Two horizontal wooden frames were placed in the channel on 2 Nov. 1993. Four spherical plastic containers containing four stones (8 to 10 cm in diameter) were fastened to each frame. Each container consisted of two hemispherical mesh baskets (mesh size, 0.8 cm) joined together by screws and wing nuts as in Fig.1. Into four of the eight containers, four adult *Hemigrapsus* (2 males and 2 females; mean carapace widths ± 1 SE, 1.9 ± 0.35 cm for males and 2.1 ± 0.06 cm for females) were enclosed, while the crabs were excluded from the other containers. We also placed another set of experimental habitats in which the containers had a 3.0 cm gap for allowing the crabs to go in and out freely, but these were accidentally lost. On 16 Dec. 1993 (44 days after being set out), the two type of experimental habitats (with and without the crabs) were carefully pulled up from the water, and the colonized small animals and the

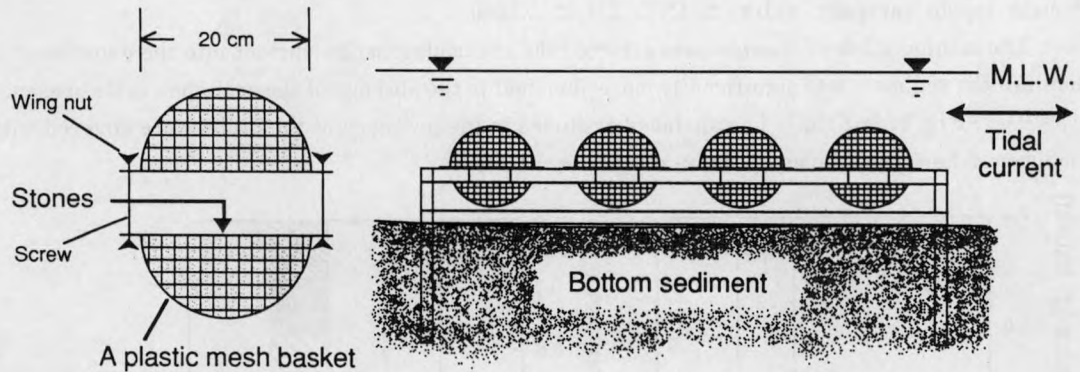


Fig. 1 The experimental habitat. The spherical containers consisting of two hemispherical mesh baskets were tightly fastened to the wooden frames by nylon fishing line.

accumulated sediment were washed off in a bucket containing water. The small animals were collected onto a 0.5 mm mesh sieve, and fixed with 10% buffered formalin. The animals were sorted, identified, and counted in the laboratory. The sediment in the water passing through the 0.5 mm mesh sieve was also collected using a 0.063 mm mesh sieve and then weighed after drying at 40°C for 72 h.

Okamoto & Kurihara (1987) found that the *Hemigrapsus* population has a two-year life span and consists of two size (age) classes. The crabs used in this study were from the larger size class. The density (4 crabs per one container = 955 crabs/m³) was lower than that observed in Okamoto & Kurihara's stone-filled trap which allowed the crabs to go in and out freely (c.a. 2500 – 5500 crabs/m³ = 10 – 23 crabs per one container; calculated based on the studies by Okamoto & Kurihara, 1987; 1989). Since the settlement of *Hemigrapsus* reaches a maximum density from Sep. to Oct. (Okamoto & Kurihara, 1987), and that of barnacles and oysters which change the habitat structure reach their maximum density from Aug. to Sep. (Matsumasa, 1994), these effects of the additional settlements of crabs, barnacles, and oysters were excluded in this experiment from Nov. to Dec.

The Kolmogorov-Smirnov one-sample test was used for examining the normalities of the distributions of data and of some transformed data (square root, logarithmic, and/or arcsine square root transformations). However, in some sets of data, none of the transformations produced normal distributions required for parametric methods. Therefore, the effects of the presence/absence of *Hemigrapsus* on the colonizations of small animals and on the sedimentation was examined by a non-parametric method, the Mann-Whitney *U* test, using SYSTAT (Wilkinson, 1992).

Results

In three of the four experimental habitats with *Hemigrapsus*, one crab disappeared from each (i.e., the number of crabs enclosed decreased from four to three). All crabs disappearing were

female (mean carapace width \pm 1SE, 2.0 ± 0.10 cm).

The manipulation of *Hemigrapsus* affected the accumulation of sediment into the experimental habitat: the sediment was significantly more abundant in the absence of the crab than in its presence ($p < 0.05$; **Fig. 2**, left fig.). The surfaces of stones in the presence of the crabs were covered with sediment; however, those in their absence were clear.

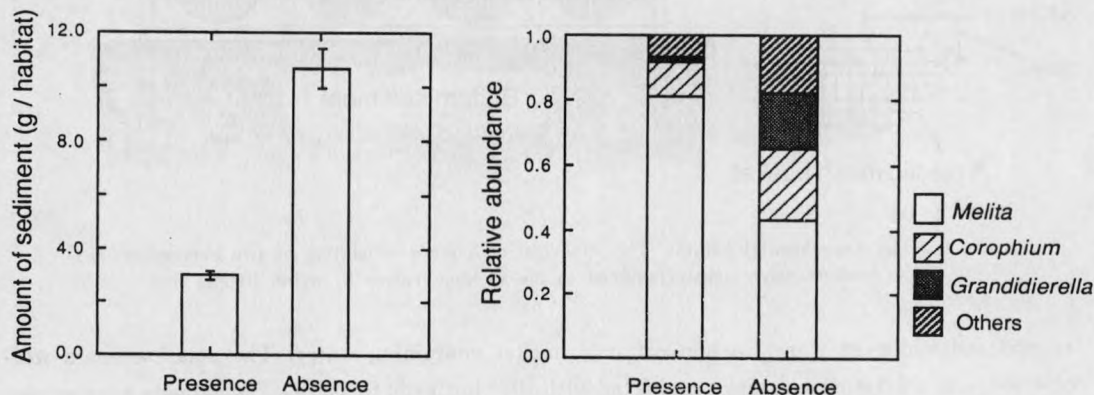


Fig. 2 The amount of sediment accumulated (mean \pm 1SE; left fig.) and the relative abundances of small animals (right fig.) in the experimental habitats with vs. without *Hemigrapsus*. The relative abundances of all the small animals except *Melita*, *Corophium*, and *Grandidierella* (the three most abundant species) were subsumed under 'others'.

Only an amphipod *Melita setiflagella* showed a significant increase in its relative abundance in the presence of *Hemigrapsus* than in its absence ($p < 0.05$; **Fig. 2**, right fig.). The relative abundance of two tube-building amphipods *Corophium uenoi* and *Grandidierella japonica* were significantly lower in the presence of the crabs than in their absence ($p < 0.05$). For the other small animals, the relative abundance of a free-living amphipod *Jesogammarus hinumensis*, a free-living isopod *Gnorimosphaeroma rayi*, and a tube-building annelid *Pseudopolydora kempji japonica* were also lower in the presence of the crabs than in their absence ($p < 0.05$).

The total abundance of small animals tended to be high in the absence of the crab, but the difference was not significant between the treatments ($p = 0.77$; **Table 1**). The abundance of *Melita* did not differ significantly either ($p = 0.25$), although it was high in the presence of *Hemigrapsus*. On the other hand, four tube-building (*Corophium*, *Grandidierella*, *Neanthes*, and *Pseudopolydora*) and two free-living (*Jesogammarus* and *Gnorimosphaeroma*) species were significantly more abundant in the absence of the crabs ($p < 0.05$). Five species appeared only in the absence of the crabs, and these species require the sediment for their living sites. Species richness (number of species) was significantly higher in the absence of *Hemigrapsus* than in its presence ($p < 0.05$).

Discussion

The results of this study show the presence of *Hemigrapsus* increases the relative abundance of an amphipod *Melita setiflagella*, but decreases those of such species as *Grandidierella japonica* and *Corophium uenoi* (**Fig. 2**). Since a set of experimental habitats of which the crabs had the run

Table 1
Abundances and number of species (mean \pm 1SE / habitat) of small animals on the two types of the experimental habitats. Asterisks indicate significantly higher values (Mann-Whitney *U* test; $p < 0.05$).

Species	Presence / absence of <i>Hemigrapsus</i>	
	Presence	Absence
<i>Melita setiflagella</i>	309.8 \pm 74.27	192.0 \pm 58.98
<i>Corophium uenoi</i>	34.0 \pm 7.76	89.3 \pm 22.21*
<i>Grandidierella japonica</i>	6.5 \pm 2.40	78.3 \pm 24.23*
<i>Jesogammarus hinumensis</i>	2.5 \pm 1.56	23.3 \pm 4.72*
<i>Gnorimosphaeroma rayi</i>	15.0 \pm 1.63	25.3 \pm 3.59*
<i>Sinelobus</i> (= <i>Tanais</i>) <i>stanfordi</i>	1.8 \pm 0.85	2.0 \pm 0.41
<i>Dimorphostylis</i> sp.	0	0.3 \pm 0.25
<i>Hemigrapsus penicillatus</i>	2.5 \pm 1.19	2.8 \pm 1.11
<i>Neanthes japonica</i>	0.3 \pm 0.25	6.8 \pm 1.55*
<i>Pseudopolydora kempii japonica</i>	0	2.3 \pm 1.11*
<i>Prionospio japonicus</i>	0	1.8 \pm 1.18
<i>Heteromastus filiformis</i>	0	0.3 \pm 0.25
unidentified nematode	0.3 \pm 0.25	0.8 \pm 0.25
<i>Nuttallia olivacea</i>	0	0.3 \pm 0.25
Total abundance	372.5 \pm 76.19	425.0 \pm 113.97
Number of species	6.8 \pm 0.95	10.5 \pm 0.65*

was accidentally lost, we could not determine the roles of the crab in natural habitats; however, Okamoto & Kurihara (1989) reported that *Melita setiflagella*¹⁾ was the most abundant among the top tree dominant small animals in their stone filled containers of which the crabs had the run

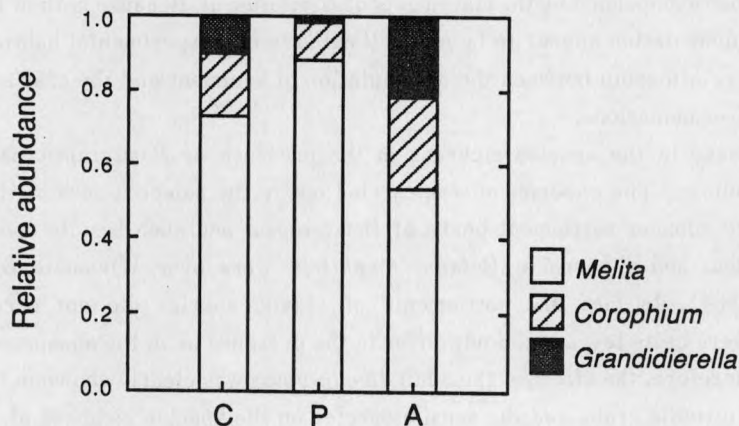


Fig. 3 The relative abundances of the top three dominant small animals in the three types of habitats. (C) Okamoto & Kurihara's stone-filled basket trap in which *Hemigrapsus* could go in and out freely (based on the data on Sep. 1984; Okamoto & Kurihara, 1989), (P) the experimental habitats with the crabs in this study. (A) the experimental habitats without the crabs in this study.

¹⁾ Okamoto & Kurihara (1989) referred to this species as *M. koreana*.

(Fig. 3). Based on an analysis of the *Hemigrapsus* population structure in the Gamo Lagoon (Okamoto & Kurihara, 1987), the density of the crabs used in this study was lower than that observed for Okamoto & Kurihara's stone-filled container (see also, **Materials and Methods**). Therefore, the presence of *Hemigrapsus* appears to affect the relative abundance of small animals in the habitats in which the crabs can go in and out freely.

The crab *Hemigrapsus* is an omnivore, and its carnivorous nature has been described (Kurihara & Okamoto, 1987; Okamoto & Kurihara, 1989; Matsumasa & Shiraishi, 1993). In a laboratory experiment, Matsumasa & Shiraishi (1993) showed that susceptibility of a free-living amphipod *Melita* to the crab predation was strikingly lower than that of a sluggish tube-building *Grandidierella*. In addition, it was observed that another tube-building amphipod *Corophium* was more susceptible to *Hemigrapsus* predation than *Melita* (pers. obs.). Because the abundance of *Melita* was not affected by the presence/absence of the crabs, and that of *Grandidierella* and *Corophium* was decreased by the presence of the crabs (Table 1), the relatively severe predation of the crab on such vulnerable small animals as *Grandidierella* and *Corophium* probably reflected the highest relative abundance of *Melita* whose susceptibility to the predation was low.

Another possible mechanism for the increase in the relative abundance of *Melita* in the presence of *Hemigrapsus* is the reduction of sediment by the crab (Fig. 2). Of the six species which decreased in the presence of *Hemigrapsus*, four were tube-builders which required the sediment (Table 1). It seemed that the crabs reduced the sediment for the living sites of the tube-building species, and then decreased their abundance. This may be related to the low species richness in the presence of *Hemigrapsus*. All five species which did not appear in the experimental habitat with *Hemigrapsus* also require sediment for their living sites. The reduction of sediment by *Hemigrapsus* may be due to the crab's feeding and/or moving. In the Gamo Lagoon, it is frequently observed that the omnivorous crab feeds on attached materials on hard substrates. On the other hand, deposited sediment may be resuspended by the movements of *Hemigrapsus*. Because both of these effect of the crab on the sedimentation appear to be overestimated in our experimental habitat which enclosed the crabs, the relationship between the accumulation of sediment and the crab's activity requires more detailed examinations.

The decrease in the species richness in the presence of *Hemigrapsus* is also one of our interesting findings. The experiment was carried out in the selected season (from Nov. to Dec. 1993) after the summer settlement peaks of *Hemigrapsus* and such sessile species as an oyster *Crassostrea gigas* and a barnacle *Balanus amphitrite* were over (Okamoto & Kurihara, 1987; Matsumasa, 1994). In fact, the settlements of sessile species did not occur, and those of *Hemigrapsus* were quite few and did not differ in the presence or in the absence of the adult crabs (Table 1). Therefore, the effect of the adult *Hemigrapsus* was clearly shown in this study, but the effects of the juvenile crabs and the sessile species on the species richness of the small animals remain unknown and are worth investigating. Since the number of newly settled *Hemigrapsus* (carapace width < 3.0 mm) from Sep. to early Oct. are expected to be over 70 individuals per our experimental habitat (calculated based on Okamoto & Kurihara, 1987), biological interactions such as competitions and predations between the juvenile *Hemigrapsus* and the other small animals are predicted. On the other hand, settlements of sessile species are important for small animals in the

structural modifications of habitats. With the growth of sessile species, substrate surfaces and micro-habitats as living sites for small animals increase. This process was referred to as 'habitat provision' in which the body of an inhabitant provides secondary space for colonizations by other species (Nishihara, 1992a; 1993), and has been considered one of the mechanisms involved in the promotion and maintenance of biodiversity (Mukai, 1978; 1990; Nishihara, 1992b; Matsumasa & Nishihara, 1994). The habitat structures provided by barnacles and oysters harbour a variety of small animals (Tsuchiya & Hirano, 1985; Bros, 1987), especially that of the oyster *Crassostrea* is an important factor which directly determines the species composition of the small crustaceans in the Gamo Lagoon (Matsumasa & Kikuch, 1993b; Matsumasa, 1994). In this lagoon, the surfaces of hard substrates (including boulders) under Mean Low Water are dominated by the oysters through successive sequences of sessile species. The oyster bed is dominated by *Melita* as well as the boulder habitat, but has more small crevices and narrow spaces than the boulder habitat lacking oysters. These micro-habitats created by the oysters would offer refuge from the larger *Hemigrapsus* to small animals which are susceptible to the crab predation and, with the accumulation of sediment in them, would provide living sites for infaunal species. In addition, Matsumasa (1994) also reported that the oyster cover was high at sites where the sedimentation rate was low, although the mechanism was unknown. Since this study showed that the amount of sediment was reduced by the presence of *Hemigrapsus*, the relationships between the activities of the crab, the sedimentation, and the colonizations of sessile species are worth investigating for understanding mechanisms in controlling the community structure.

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References

- Bros, W. E (1987) Effects of removing or adding structure (barnacle shells) on recruitment to a fouling community in Tampa Bay, Florida. *J. Exp. Mar. Biol. Ecol.*, **105**, pp. 275-296.
- Fukui, Y. and K. Wada (1986) Distribution and reproduction of four intertidal crabs (Crustacea, Brachyura) in the Tonda River Estuary, Japan. *Mar. Ecol., Prog. Ser.*, **30**, pp. 229-241.
- Goshima, S., M. Izawa and Y. Ono (1978) A preliminary study on the habitats and daily activities of some grapsid crabs and a land crab. *Benthos Res.*, **15/16**, pp. 28-33 (in Japanese).
- Kikuchi, E. and H. Mukai (1994) Bioturbation: changes produced by benthos in sediment environments. *Benthos Res.*, **46**, pp. 59-79 (in Japanese with English abstract).
- Kurihara, Y. and K. Okamoto (1987) Cannibalism in a grapsid crab, *Hemigrapsus penicillatus*. *Mar. Ecol., Prog. Ser.*, **41**, pp. 123-127.
- Matsumasa, M. (1994) Effect of secondary substrate on associated small crustaceans in a brackish lagoon. *J. Exp. Mar. Biol. Ecol.*, **176**, pp. 245-256.
- Matsumasa, M., and Y. Kurihara (1988) Distribution patterns of benthic small crustaceans and the environmental factors in a brackish shallow-water lagoon, Gamo-Lagoon. *Benthos Res.*, **33/34**, pp. 33-41 (in Japanese with English abstract).

English abstract).

- Matsumasa, M. and K. Shiraishi (1993) Susceptibilities of brackish small crustaceans to potential predators. *Ann. Rep. Iwate Med. U. Sch. Lib. Arts & Sci.*, **28**, pp. 29-36.
- Matsumasa, M. and S. Kikuchi (1993a) Blood osmoregulatory type and gill ultrastructure of an estuarine crab *Hemigrapsus penicillatus* (de Haan) (Crustacea; Brachyura). *Ann. Rep. Iwate Med. U. Sch. Lib. Arts & Sci.*, **28**, pp. 37-45.
- Matsumasa, M. and E. Kikuchi (1993b) Teisei Kogata koukakurui no bunpu to nagare: chokusetu sayo to sumikomi kankei wo kaisita kansetu sayo. *Kaiyo Monthly*, **25**, pp. 269-276 (in Japanese).
- Matsumasa, M. and M. Nishihara (1994) Habitat structure provided by *Mytilus edulis* and the modification by sessile inhabitants. *Bull. Mar. Biol. Stn. Asamushi, Tohoku Univ.*, **19**, pp. 51-63.
- McLusky, D. S. (1989) *The Estuarine Ecosystem*. 2nd ed. Blackie, Glasgow and London, 215 pp.
- Menge, B. A., E. L. Berlow, C. A. Blanchette, S. A. Navarrete and S. B. Yamada (1994) The keystone species concept: variation in interaction strength in a rocky intertidal habitat. *Ecol. Monogr.*, **64**, pp. 249-286.
- Mukai, H. (1978) A comprehension about biotic community in seagrass and sea-weed beds: another view of interspecific relationships. *Benthos Res.*, **15/16**, pp. 87-93 (in Japanese).
- Mukai, H. (1990) Macrophyte-phytal organisms interactions. In, *Introduction to applied phycology*, edited by I. Akatsuka, SPB Academic Publishing, The Hague, The Netherlands, pp. 347-365.
- Nishihira, M. (1992a) Biotic creation of habitat structure and multi-species coexistence. In, *What is symbiosphere?*, edited by M. Higashi and T. Abe, Heibon-sha, Tokyo, pp. 86-100 (in Japanese).
- Nishihira, M. (1992b) Biotic generation of habitat structure and promotion of multi-species coexistence in coral reefs. Int. Symp. on *Biodiversity and adaptive strategies of coralreef organisms* (abstract), University of the Ryukyus, Okinawa.
- Nishihira, M. (1993) Habitat structure and biodiversity in the coral reef area: ecological process in habitat creation and community development on microatolls of the massive coral *Porites*. In, *Symbiosphere, ecological complexity for promoting biodiversity*, edited by K. Kawanabe, T. Ohgushi, and M. Higashi, IUBS Biology International, **29**, pp. 26-29.
- Ogura, M. and Y. Kishi (1985) Reproductive period and occupation of empty beverage cans by males of the crabs, *Hemigrapsus penicillatus* (de Haan). *Jpn. J. Ecol.*, **35**, pp. 377-385 (in Japanese with English abstract).
- Okamoto, K. and Y. Kurihara (1987) Seasonal variation of population structure of *Hemigrapsus penicillatus* (de Haan) (Crustacea: Brachyura). *Jpn. J. Ecol.*, **37**, pp. 81-89 (in Japanese with English abstract).
- Okamoto, K. and Y. Kurihara (1989) Feeding habit and food selection of the grapsid crab *Hemigrapsus penicillatus*. *Jpn. J. Ecol.*, **39**, pp. 195-202 (in Japanese with English abstract).
- Ono, Y. (1959) The ecological studies on Brachyura in the estuary. *Bull. Mar. Biol. Stn. Asamushi, Tohoku Univ.*, **9**, pp. 145-148.
- Paine, R. T. (1966) Food web complexity and species diversity. *American Naturalist*, **100**, pp. 65-75.
- Putman, R. J. (1994) *Community Ecology*. Chapman & Hall, London, 178pp.
- Rhoads, D. C. and D. K. Young (1970) The influences of deposit-feeding organisms on sediment stability and community trophic structure. *J. Mar. Res.*, **28**, pp. 150-178.
- Tamaki, A. (1984) Structural characteristics of an intertidal sand flat in Tomioka Bay, Amakusa, west Kyushu. *Publ. Amakusa Mar. Biol. Lab. Kyushu Univ.*, **7**, pp. 125-150.
- Tsuchiya, M. and Y. Hirano (1985) Distribution of intertidal animals and associated fauna of the patch of oyster *Crassostrea gigas* on the rocky shore of Mukaishima Island, Hiroshima, southwestern Japan. *Bull. Biol. Soc. Hiroshima Univ.*, **51**, pp. 3-9.
- Wilkinson, L. (1992) *SYSTAT: Statistic, version 5.2 edition*. Evanston, IL: SYSTAT, Inc., 724 pp.
- Wilson, W. H. (1981) Sediment-mediated interactions in a densely populated infaunal assemblage: the effects of the polychaete *Abarenicola pacifica*. *J. Mar. Res.*, **39**, pp. 735-748.