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Life History of Sand-Burrowing Amphipod *Haustorioides japonicus* (Crustacea: Dogielinotidae)

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Abstract

The amphipod *Haustorioides japonicus* KAMIHIRA is the dominant crustacean on the sandy beaches around southern Hokkaido. The present paper deals with the materials obtained at Omori beach, Hakodate, for 5 years from 1971 to 1976. This amphipod is found exculsively in the littoral zone from June to November, and disappears from the beach for the rest of the year by burrowing in the infralittoral zone. The reproductive season begins in early June and lasts until early August with five notable spawning periods. The generation seems to be completed within a year. The sex ratio is 1:1 during in the first half of the breeding season, but it becomes 1:2 in the latter half of the season, due to a sudden increase in deaths among male members. The regression equation of body length (L)–dry weight (W) relationship for *H. japonicus* can be expressed as $W=0.0189\ L^{2.606}$. Numbers of eggs per brood are 77.6 ± 20.4, with a range from 13 to 142, depending upon the body length.

Introduction

According to Bousfield[1], dogielinotid amphipods are sand-burrowers and are widely distributed in the shallow coastal waters around the North Pacific. Two species, *Haustoriodies munsterhjelmi* and *H. japonicus*, have been known in the genus *Haustorioides*. Of these the latter was first described by the present author in 1977[2]. *H. japonicus* occurs abundantly in the littoral zone of the sandy beach around Hakodate in southern Hokkaido, and at some locations along the coast of the nearby Volcano Bay. There is little known about the life history of Dogielinotidae in the Pacific region[3], but many contributions have been made to understanding the life history of Haustoriidae from North America and Europe [4–11]. This study aims to provide knowledge about the biology of *H. japonicus*.

Materials and methods

The study area, Omori-beach of Hakodate, is located on the eastern side of the tombolo which connects Mt. Hakodate and Oshima peninsula (Fig. 1). The width from shoreline to embankment is approximately 35 m in MLWST. The beach profile shows a smooth easy grade shore type. The sea bed close to the

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shoreline was composed of fine, medium and coarse sand grains, which represent 77% of all the sediments. The Warm Tsugaru Current washes slightly onto the beach from summer to winter, but the Oyashio occurs in the Spring[12]. Mean tidal amplitude on the beach is 0.55 m. Salinity varied annually from 30.64 to 33.48‰ during the observation period (Fig. 2). The decrease in salinity was related to heavy rainfall and thaw. Water temperature was low in February (7.0 °C), and high in August (24.1°C).

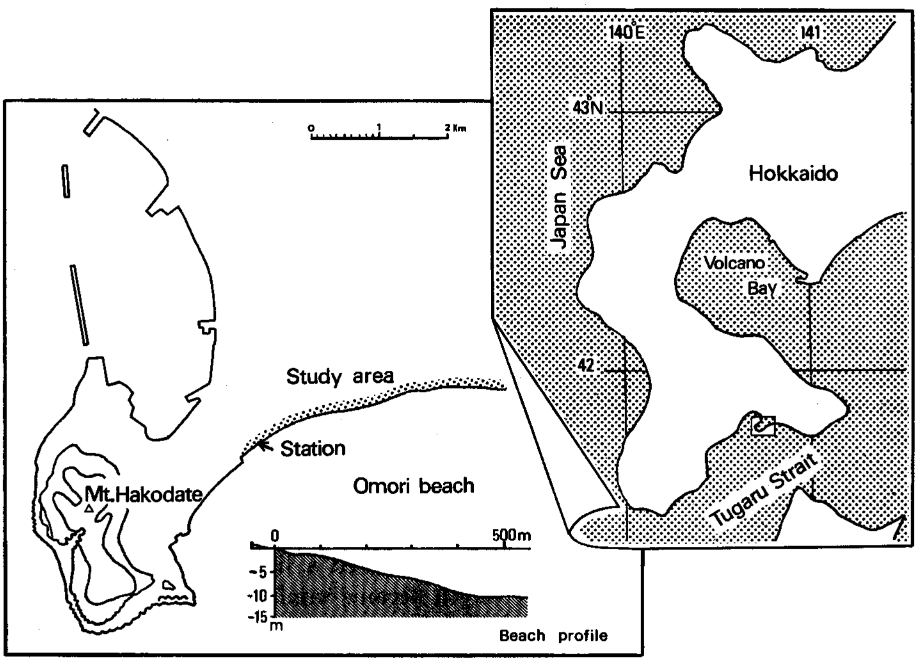

Fig. 1. Location of the study area.

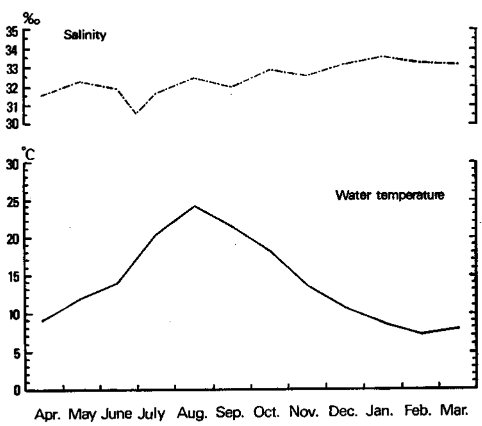

Fig. 2. Monthly mean water temperature and salinity on littoral zone in the study area, June 1971–July 1976.

Investigations were conducted once or twice a month for 5 years from June 1971 to June 1976. Additional investigations were carried out to obtain ovigerous females in short intervals of 3–5 days from June to August in 1977. The study site was set up corresponding to a minute section of the topography on shore, such as the beach cusp. The sand samples were taken with a metal or plastic core sampler of 30 cm^2 in basal area, 10 cm in height. A total of 50–100 core samples were collected on each sampling day. Immediately after putting those samples into nylon bags, they were carried to the laboratory. First, the animals were separated from the sand by using a rough flotation method, and then the animals remaining with the sediments were sorted out by hand.

The body length of *H. japonicus* was determined with a binocular microscope, by measuring, with 250 μ preciseness the distance from the tip of the rostrum to the end of the telson. In determining the dry weight, the animals were kept in an oven at 80°C for 24 hrs, and then transferred to a desiccator. A Mettler balance was used for weighing the dried materials.

Results

1. *Annual growth*: *H. japonicus* began to occur in the littoral zone during the first half of June, when the water temperature reached about 14–16 °C, and remained there until mid-October or November. Both males and females were observed only in mid-June and July every year. They remained on the beach until mid-November in 1971, 1972 and 1975, but there were no animals left at that time in 1973 or 1974. Fig. 3 shows the frequency distribution of the body size in both sexes and in juveniles of *H. japonicus* from 1971 to 1975. The mean body length was 9.0±0.5 mm in the male and 10.3±0.4 mm in the female. In 1971, 1973 and 1975 the recruitment of juveniles possibly occurred a little earlier than in 1972 and 1974. Size composition of body length became samller in 1972 and 1974. In mid-July various sizes of juveniles from 1.4–6.0 mm were observed, and the peak of recruitment of juveniles was also found. The size of juveniles which were collected in mid-August ranged between 2 and 7 mm. A remarkable increase to 5–8 mm of body length was observed in mid-September and October, and the range of size distribution became narrower than that of August (1.5–5 mm). The range of body size of the specimens that were collected in mid-November was biased somewhat toward the larger size, but the range was narrower than that of October. There were no juveniles with a body length larger than 8mm in the littoral zone. Although the mode of body length was 7mm in November as well as in October, the occurrence frequency at 7 mm was about 10% higher in November than in October. *H. japonicus* disappeared completely from the littoral zone from December to May, due to the migration down to the infralittoral zone. The size distribution of *H. japonicus* that migrate to the infralittoral zone could be examined from a small number of specimens obtained from water samples in the littoral zone, though no specimens were found on the sand. It seems that the inhabitation of *H. japonicus* is inevitably transferred from the infralittoral zone to the littoral zone because of the stormy weather. The mode of body length was 7 mm in December and January, as in November, but changed to 8 mm in

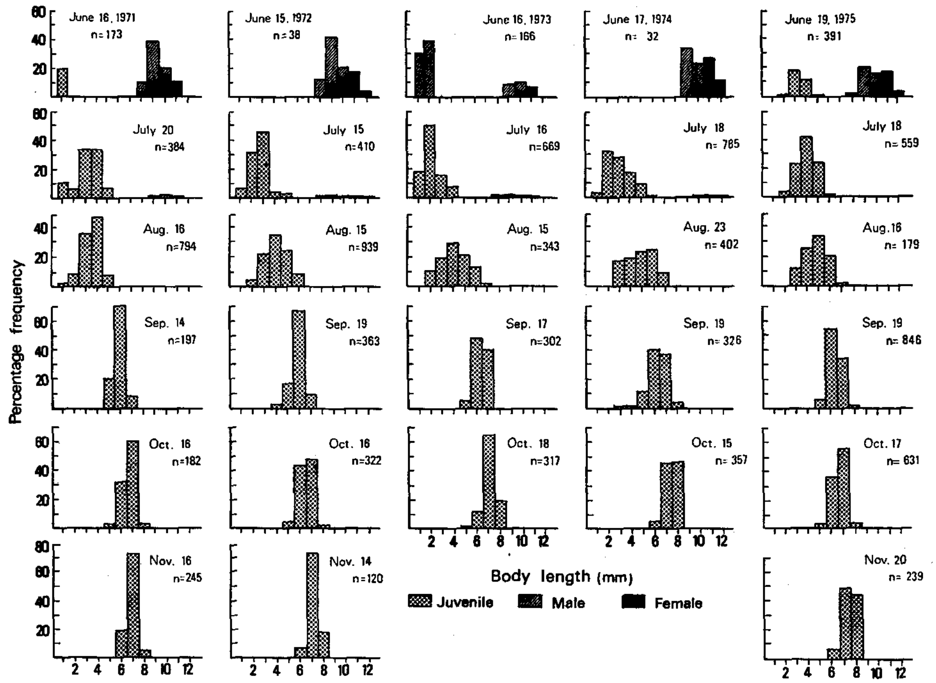

Fig. 3. Frequency distribution of body size in both sexes and juveniles of *Haustorioides japonicus*.

February. In March and April the mode was 8 mm, and the range of body size was biased somewhat toward the larger size. The mode in mid-May reached 9 mm.

Growth observation of *H. japonicus* was made from June 1971 to June 1972 (Fig. 4). Juveniles (body length of 1.40 mm, 0.017 mg dry weight) which hatched in mid-June grew by a rate of 0.5–1.0 mg/month until the following February, with a rapid increase observed in the latter half of August and September. It was difficult to distinguish morphologically between male and female before determining secondary sexual characteristics. Secondary sexual characteristics distinguished in the males were slightly enlarged 2nd gnathopods and a rapid increase in the number of setae in dactylus of 5th pereopods; this characteristic was also found in some individuals of the small size group. Division of groups into large female and small male occurred in March. The large female group showed about 1.1 mg/month of growth rate, whereas the small male group grew at 0.5 mg/month. In June, the growth of females was 10.8 ± 1.0 mg on an average, whereas that of males was 7.8 ± 0.9 mg.

The length-weight relationship for both sexes of adults and juveniles of *H. japonicus* is shown in Fig. 5 and the curve was given by the following formula:

$$W = 0.0189\,L^{2.606}$$

where W: Body weight (mg dry weight), L: Body length (mm).

2. *Breeding behavior*: Six ratio was examined on matured animals, since it was difficult to identify sex in juveniles. Sex ratios of female to male ranged from

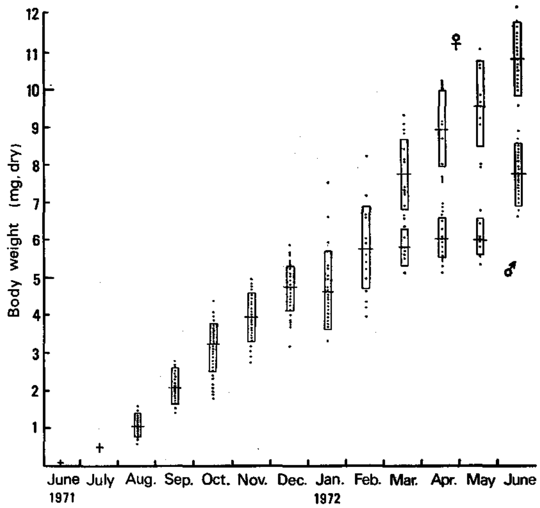

Fig. 4. Growth of *Haustorioides japonicus*. Juveniles hatched in mid-June grew by a rate of 0.5–1.0 mg per month until the following February. In March the population began to differentiate into two different size groups. The larger group grew into females, and the smaller one grew into males.

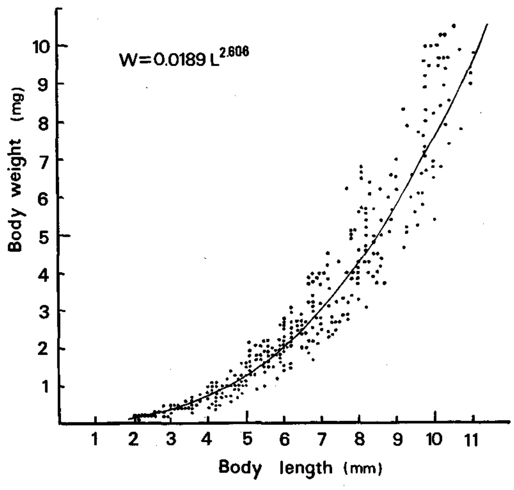

Fig. 5. Relationship between body length and body weight (dry, mg) of *Haustorioides japonicus*.

1:0.51 to 1:1.29 according to 12 observations of 63 samples series in June and July, 1971–1975 (Table 1). The mean ratio was significantly different from 1:1 by a Chi square test for equality ($p<0.01$). In additional observations on 14 samples collected very three or four days from late June through early August, 1977, it was shown that the sex ratio varied considerably during the breeding season; it varied

Table 1. *The sex ratio of females to males in Haustorioides japonicus.*

Date	Male (N./m²)	Female (N./m²)	Femle/Male
16 VI 1971	910	820	0.901
20 VII	180	140	0.778
15 VI 1972	105	100	0.952
30 VI	360	310	0.861
15 VII	190	150	0.789
16 VII 1973	260	210	0.808
29 VI	640	660	1.031
16 VII	110	140	1.272
17 VI 1974	175	225	1.286
18 VII	245	125	0,510
19 VI 1975	560	560	1.000
2 VII	199	198	0.995
mean			0.932

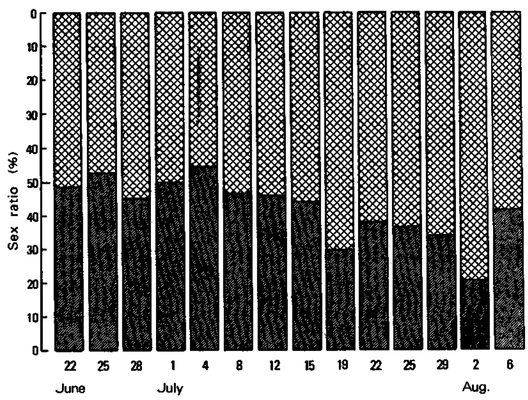

Fig. 6. Changes of sex ratio during the breeding season, June-Aug. 1977 in *Haustorioides japonicus.* ▨ Male, ▩ Female

1:1.05 in the first half and 1:2.00 in the second half (Fig. 6). The changes in the ratio probably are due to a rapid death of the male after copulation. A high ratio of males was observed on August 6; however, the absolute density of adults was very low. Most of the matured specimens died before mid-August.

Ovigerous females were found in the littoral zone from mid-June to early August. Courtship behavior was observed from early June through early August. In courtship, the male rides on the female's back (Fig. 7). Dactylus of the 1st gnathopods of the male were hung between the 2nd pereonal segment and coxal plate of the 2nd pereopods in female. The 2nd gnathopods were not used for this purpose. The pairing involved such close contact that the paired couple swam actively in the water or even burrowed into the sediment. The same pose as that of copulation known of *Gammarus locusta*[13] was often observed in couples burrowing in the wet sand. That is, the male, on his back under the body axis of female, bent his body at almost a right angle, wrapping it around that of the female. The

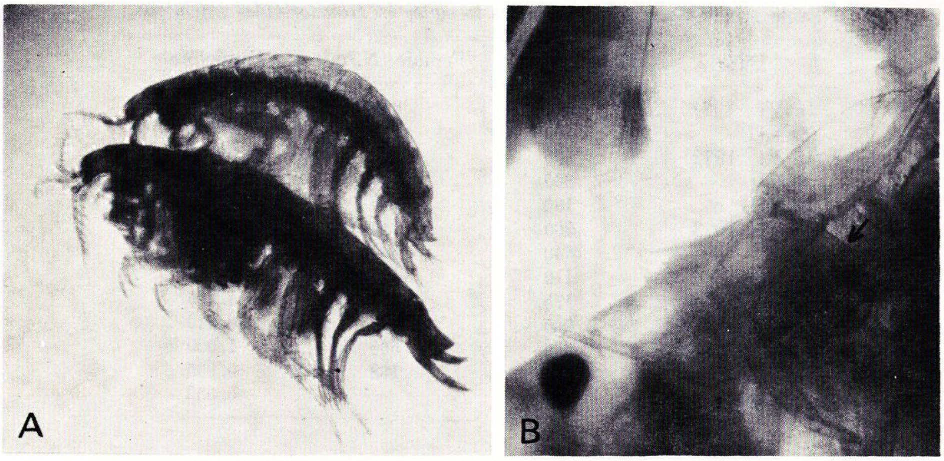

Fig. 7. The amphipod *Haustorioides japonicus*. A: A mature male is seen riding on a large female, B: Dactylus of the 1st gnathopods of the male are hung between the 2nd pereonal segment and coxal plate of the 2nd pereopods in female.

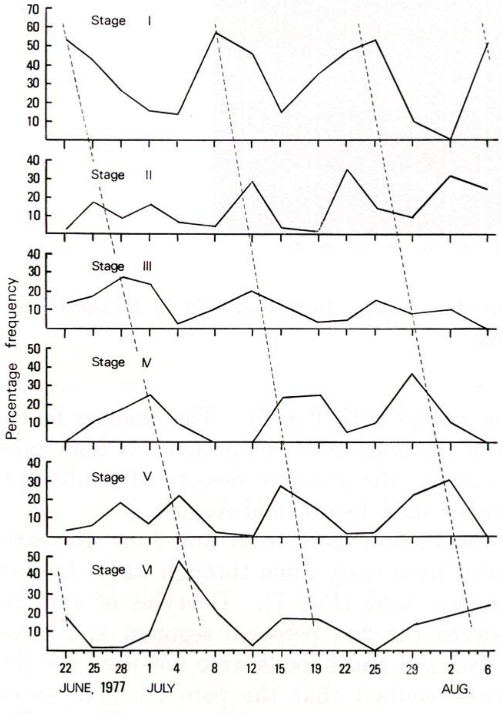

Fig. 8. The seasonal occurrence of ovigerous females of *Haustorioides japonicus* by the development stages of eggs I-VI.

body was bent forward and his thorax was brought into contact with the female's. Copulation was not seen at all in the water. Different from most gammaridean amphipods, the female is a little larger than the male in *H. japonicus*.

3. *Fecundity*: Several developmental phases of eggs in ovigerous females were observed between June and August (Fig. 8). The developmental stages were as follows:

Stage I. Uncleavage eggs.
Stage II. Cleavage eggs, development of the germinal disc and appearance of the dorsal rudiment.
Stage III. Formation of the caudal furrow and appearance of appendage rudiments.
Stage IV. Segmentation of all the appendages.
Stage V. Appearance of pig-

ment spots on the rudiments, beating of the heart, further reduction of the dorsal organ, and muscular movement, especially in the gut.

Stage VI. Hatched juveniles visible inside the brood lamellae.

The peaks of occurrence of stage I were observed on June 22, July 8, July 25 and August 6, while the peaks of stage VI were found on June 22, July 4, July 19 and August 6. Developmental stage I occurred infrequently because of the natural death of matured females after August 6. As the females died by mid-August, no juveniles could be recruited. Judging from the changes in the peaks between stages, the number of broods produced during the summer was estimated in a local population. The female, therefore, appears to produce five broods during the breeding season, but actually four of those may survive until the next season.

The number of eggs per brood (N) was plotted against the body length (L) of the ovigerous female (Fig. 9). It was shown that there was a highly significant relationship (r=0.767) for which the regression equation is:

$$N = 21.242\,L - 129.64$$

It may be considered that one female of *H. japonicus* having 9.75 mm in mean body length lays an average of 78 eggs per brood. The minimum body length of ovigerous females was 7.4 mm.

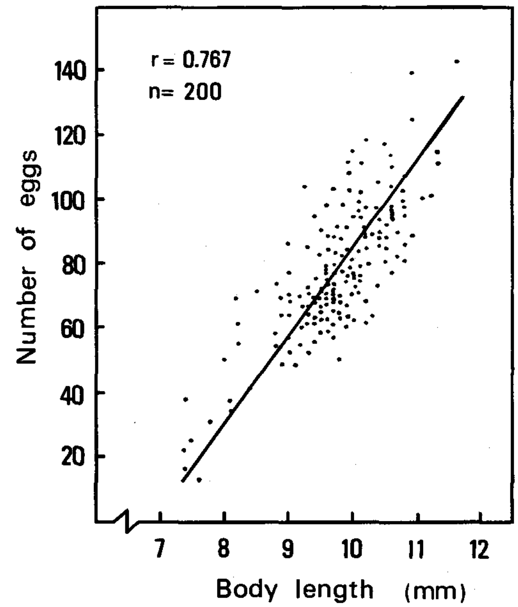

Fig. 9. The relationship between the number of eggs per brood and body length in *Haustorioides japonicus*.

Discussion

The longevity of marine gammaridean amphipods has been estimated by sythetic examination, such as the examination of monthly frequency distributions of body length, the occurrence periods of adults specimens and the occurrence rate of ovigerous females in each sample, based upon field samples over a whole year. The greater part of marine species of which the longevity is known belong to the family Haustoriidae. According to hitherto reports, the longevity of sand-burrowers varies according to species and cohort; for example, members of the summer generation of *Neohaustorius schmizi* stay alive for four months, while those of the winter generation live for eight months[8]. *Bathyrporeia sari*, *Parahaustorius longimerus*, *Protohaustorius deichmannae*, *Haustorius canadensis* and *Neohaustorius biarticulatus* show approximately one year life spans[5,6,9]. *Acanthohaustorius millsi* has a life span of one to one and a half years[5]. *In Urothoe brevicornis*, the male lives for about one year, whereas the female lives for about two years[9]. It has been reported that *Haustorius arenarius* may possibly survive for 2–3 years[9]. *Neohaustorius schmizi* is considered to possibly have the shortest life span of any species. As for the species of Dogielinotidae, according to the latest volume of the "Amphipod Newsletter", which I received recently, *Dogielinotus loquax* has a bivoltine reproductive cycle, and the generation recruited in the spring produces in the summer a generation that overwintered and reproduces the following spring[14].

According to the monthly frequency distribution of body length in *Haustoriodies japonicus* (Fig. 3), mature male individuals attained a length of 8–10 mm, and females 9–11 mm, in the breeding period. The size of juveniles was 6–8 mm before they disappeared from the littoral zone. The growth rate of *H. japonicus* at the infralittoral zone during winter and spring was lower than that found during summer and autumn. When members of *H. japonicus* appeared in

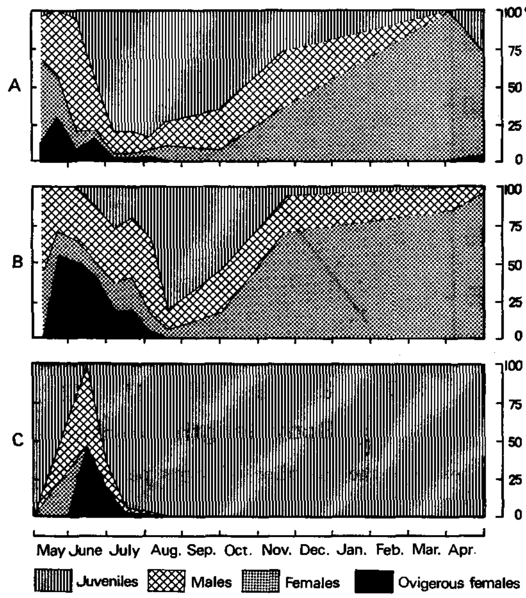

Fig. 10. Seasonal changes of percentage composition in annual type sand-burrowing amphipods. A: *Parahaustorius longimers*, B: *Protohaustorius deichmannae*, C: *Haustorioides japonicus* (A and B drawn from Sameoto's tables).

the littoral zone in June, their sex differences grew to be distinguished by dimorphism in gnathopods. It is assumed that they grew large enough to breed at this time. From late July until August, there were many remains of adult animals in the superlittoral zone. The adults, therefore, presumably die off during the mid-summer. Both the change in monthly size composition and the growth curve in *H. japonicus* strongly suggest that no matured animals which breed previously join in the breeding activity the following year. The longevity of *H. japonicus* appears to be about 12 months.

The study area used is located in 41°45'N, 140°41'E, and is situated at the same latitude as Cape Cod (41°45'N, 70°30'W). The annual change of water temperature in the littoral zone is similar in the two area; moreover, the fluctuation range of salinity is almost identical. The breeding season of *Parahaustorius longimerus* and *Protohaustorius deichmannae*, dwelling on the sandy beaches of Cape Cod, is from late spring to mid-summer, and it resembles that of *Haustorioides japonicus* in the present study area (Fig. 10). The similarity of environments in sand-burrowing amphipods may be responsible for similar life histories. Sameoto[6] reported the occurrence of the ovigerous female of the family Haustoriidae, for which the life cycle was annual, during the period from early May through mid-August; it had a few spawning peaks during the breeding season, and the mean brood size was less than ten eggs. On the contrary, the breeding season of *H. japonicus* was shorter by about a month than those of Haustoriidae, and also there were five notable spawning peaks in the season; moreover, mean brood size was 77.6±20.4 with a range of 13–142 eggs.

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