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SEASONAL CHANGES IN THE STOMACH CONTENTS OF THE BURROWING MUD-CRAB, *HELICE TRIDENS* (DE HAAN)[1]

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This study investigated seasonal changes in the feeding activity of the mud crab *Helice tridens* (De Haan). In early summer, from June to July, feeding activity was low, and the stomach contents contained a large amount of inorganic matter, suggesting that the crabs fed mainly upon surface soil. These results may be related to copulation behaviour, since the crabs are associated closely with their burrows. In contrast, in the wandering season in early fall, the organic matter fraction of the stomach contents was clearly high compared with other months, strongly suggesting that the crabs fed directly on plants and/or animals. This change in food sources in early fall was supported by observations that many large crabs wandered around in the lagoon and creek in front of the salt marsh habitat, because organisms suitable for food were abundant there. From fall to early winter, stomach fullness was at its highest. The increase in feeding activity in this season may be related to life style, since the crabs pass the winter in their burrows.

It is well known that almost all crabs, which inhabit intertidal sandy and muddy flats in brackish lagoons and river mouths, dig burrows and feed around each burrow (*e.g.* FIELDER, 1970; YAMAGUCHI, 1970; EVANS *et al.*, 1976; WADA, 1985). It has also been observed that these crabs leave their burrows and move down to the water-logged tidal flats, and feed there (*e.g.* YAMAGUCHI and TANAKA, 1974; WADA, 1981; MURAI *et al.*, 1982; HENMI, 1984). This wandering behaviour is considered to be due to the high population density and poor food or water supply in the burrowing area.

The mud crab, *Helice tridens* (DE HAAN) (Grapsidae), generally inhabits salt marshes (ONO, 1959; SATO, 1979; TAKEDA and KURIHARA, 1987a), and has frequently been observed to feed upon the surface soil containing fine organic matter. Although it makes burrows in both intertidal marshes and marshes above high tide level, it appears in lagoons and creeks in front of the salt marsh during summer and early fall (KURIHARA *et al.*, in preparation). These crabs have often been observed

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to feed upon a range of food materials there, such as fish, smaller crabs, and seaweed, suggesting that their stomach contents change seasonally.

Goshima *et al.* (1978) have reported that the feeding activity of the mud crab corresponds to the tidal rhythm, that is, the stomach contents increase at low water and decrease at high water. Nevertheless, there has been no proper description of their food sources. The types of food could not be clarified by analysis of stomach contents, because the contents in their stomach were so fine that it was impossible to identify the various components.

The purpose of the present study was to clarify seasonal changes in feeding activity of the mud crab associated with its wandering behaviour in summer and early fall. Initially, seasonal changes in food consumption and amount of stomach contents were investigated. Subsequently, the organic matter component of the stomach contents was measured seasonally. The results are considered in relation to seasonal changes in behaviour, such as mating, brooding and wandering.

Materials and Methods

Burrowing mud-crabs were collected in a salt marsh on the north side of the mouth of the Natori River, Miyagi Prefecture, in northeastern Japan (38°11′N : 140° 48′E). The salt marsh was dominated by the reed, *Phragmites australis* Trin., and submerged by brackish water twice every day as a result of tidal action. Sampling was carried out over about 30 minutes at low water of a spring tide once a month during the active season (17 June, 18 July, 18 August, 26 September and 27 October, 1981), since the crab stomach contents are highest at low water (Goshima *et al.*, 1978). All samples were preserved in 10% formalin solution at the time of sampling.

The stomach was removed from each mud-crab subsequent to measuring the carapace width using a caliper (Takeda and Kurihara, 1987a). The stomach was heart shaped, and the wall of its upper part was soft. After feeding, this upper part was swollen by the food. For this study, 100% of stomach fullness was defined as the condition where the upper part of the stomach was fully swollen by much food, and 0% was defined as that where nothing was detectable, when the stomach was cut open. Stomach fullness for particular mud-crabs was recorded at 10% intervals.

All contents in the opened stomach were washed into a separate crucible for each individual, and their weight measured after drying at 110°C for 4 days. The organic matter component in the stomach contents was taken as the difference between dry weight and the weight after burning at 700°C for 2 hours.

A soil sample from the surface to a depth of 3 mm was collected in the salt marsh habitat, and its organic matter content measured.

Results

Seasonal changes in feeding activity at low water

Figure 1 shows the seasonal change in relationship between carapace width and the index of stomach fullness; this was calculated using the average fullness at carapace width intervals of 0.25 cm. The index decreased according to increase in carapace width. This indicates that feeding activity at low water and/or the previous ebb tide was higher for small individuals than large ones throughout the sampling season. The index of stomach fullness was least in July, and then rose, reaching a maximum in October.

The frequency distribution of stomach fullness for small crabs with a carapace width of less than 2 cm, is shown in Fig. 2a, because the mud crabs investigated showed different behaviour patterns between individuals with carapace widths more or less than 2 cm (Kurihara *et al.*, in preparation). Individuals with an index less than 20% were abundant in June (22.7%) and July (36.4%). In the fall, the frequency of individuals with low stomach fullness decreased, and the index was more than 61% in October for all individuals (average 85.7%).

Figure 2b shows the seasonal change in frequency distribution of stomach fullness on large crabs with a carapace width of 2 cm and over. In general, two

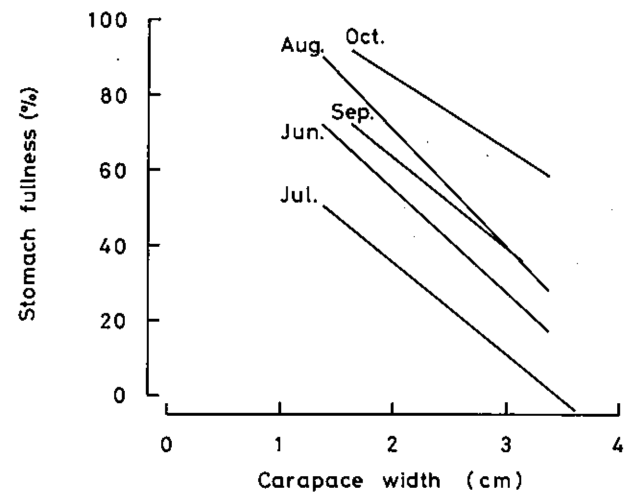

Fig. 1. Seasonal change in the relationship between carapace width and stomach fullness, calculated using the average volume at carapace width intervals of 0.25 cm.

Jun. 17 : $Y=110.1-27.6X$, $N=9$, $r=-0.759$, $p<0.05$
Jul. 18 : $Y=84.5-24.5X$, $N=10$, $r=-0.922$, $p<0.01$
Aug. 18 : $Y=133.4-31.3X$, $N=9$, $r=-0.898$, $p<0.01$
Sep. 26 : $Y=112.5-24.5X$, $N=6$, $r=-0.492$, $p>0.05$
Oct. 27 : $Y=123.3-19.2X$, $N=8$, $r=-0.732$, $p<0.05$

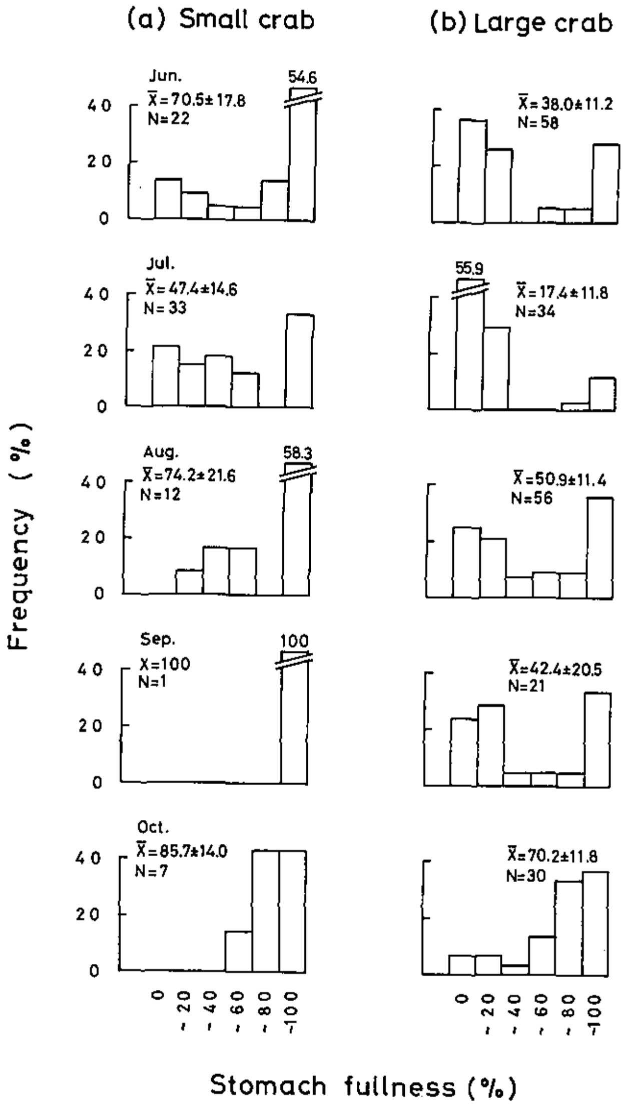

Fig. 2. Seasonal change in the frequency distribution of the index of stomach fullness for both a small crab with a carapace width of less than 2 cm (a) and a large crab with a carapace width of more than 2 cm (b).

peaks were recognized from June to September. That is, the frequency was high between 0 and 20% and between 81 and 100%. This indicates that large crabs can be divided between a group of individuals that had fed actively and a group of individuals that had spent much time on other activities at low tide. In October, the frequency distribution of stomach fullness was concentrated between 61 and 100%. This (Figs. 2a and 2b) shows that *H. tridens* fed actively at low tide in the

fall, regardless of carapace width.

Seasonal change in stomach contents

Figure 3 shows the relationship between dry weight of stomach contents and carapace width for each grade of stomach fullness divided into 6 degrees. The intercepts of the relation-expression increased with increasing stomach fullness, except for the sample with fullness between 41 and 60%. 0, 20, 40, 60, 80 and 100% stomach fullness were considered to correspond to 0, 0.04, 0.16, 0.36, 0.64 and 1.00 of the ratios by volume, because "stomach fullness" was used to indicate the horizontal extent to which the stomach was filled by food. On the basis of 100% stomach fullness, the dry weight of stomach contents corresponded roughly to the volume of food with stomach fullness between 41 and 60% and between 61 and 80%. For the grades of stomach fullness of 0% and between 1 and 20%, however, the weight of

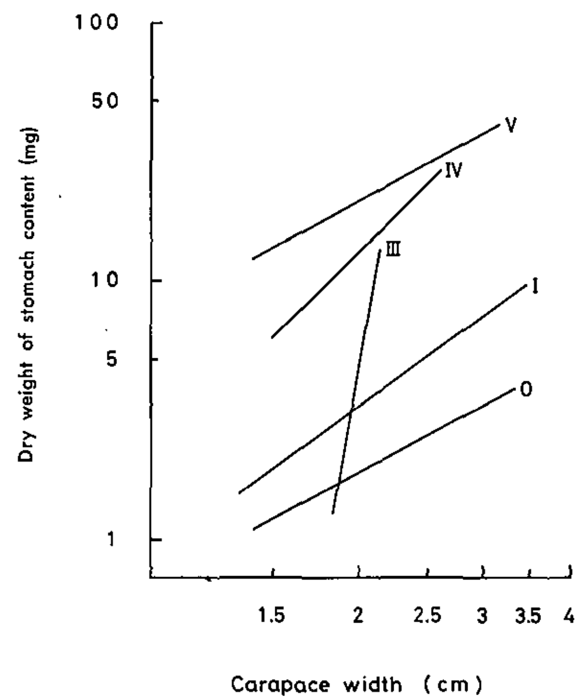

Fig. 3. Relationship between the dry weight of the stomach content and carapace width for each grade of stomach fullness on 17 June, 1981, divided into 6 grades, i.e., 0%, 1-20%, 21-40%, 41-60%, 61-80% and 81-100%.

0 (0%): $\ln Y=-0.421+1.4641\ln X$, N=23, r=0.310, $p>0.05$

I (−20%): $\ln Y=-0.184+1.974 \ln X$, N=17, r=0.514, $p<0.05$

II (−40%): N=1

III (−60%): $\ln Y=-9.086+15.436 \ln X$, N=4, r=0.925, $p>0.05$

IV (−80%): $\ln Y=0.704+2.697 \ln X$, N=6, r=0.886, $p<0.05$

V (−100%): $\ln Y=1.998+1.482 \ln X$, N=28, r=0.427, $p<0.05$

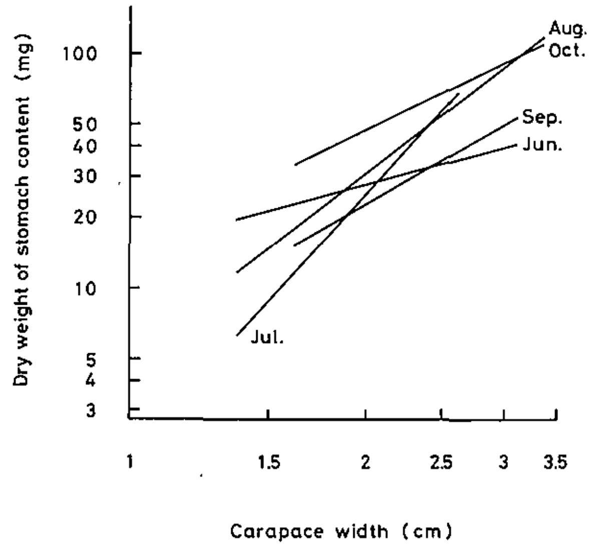

Fig. 4. Seasonal change in the relationship between the dry weight of the stomach content and carapace width for grades of stomach fullness between 81 and 100%.
Jun. 17 : $\ln Y=2.704+0.890 \ln X$, $N=8$, $r=0.588$, $p>0.05$
Jul. 18 : $\ln Y=0.673+3.692 \ln X$, $N=6$, $r=0.868$, $p<0.05$
Aug. 18 : $\ln Y=1.624+2.602 \ln X$, $N=10$, $r=0.882$, $p<0.01$
Sep. 26 : $\ln Y=1.788+1.931 \ln X$, $N=5$, $r=0.815$, $p>0.05$
Oct. 27 : $\ln Y=2.749+1.611 \ln X$, $N=7$, $r=0.874$, $p<0.01$

stomach contents exceeded the volume of food, indicating that the stomach contained fine and/or soluble foods. With stomach fullness between 81 and 100%, the dry weight of stomach contents was considered to represent food consumption during an ebb tide (Goshima *et al.*, 1978).

Figure 4 shows the seasonal change in dry weight of stomach contents for the grade of stomach fullness between 81 and 100%. The relationship showed slight seasonal differences, suggesting that the specific gravity of the food sources changed seasonally, or that the crab fed on different food sources. The weight of stomach contents increased with increase in carapace width. The maximum food-consumption was about 100 mg per ebb tide for a large crab with carapace width of 3.5 cm, and about 30 mg for a small one with carapace width of 1.5 cm. These measurements on *H. tridens* nearly correspond to ones for the grapsid crab, *Sesarma erythrodactylum* (Hara and Ono, 1976).

Figure 5 shows the seasonal changes in organic matter component of the stomach contents. In September, the organic matter content was very high ($\bar{x}=63.3\pm 10.2\%$) in comparison with other months, except for August when large crabs had a carapace width between 3.25 and 3.49 cm. In contrast, the organic matter content of the surface soil eaten by mud crabs did not vary much (Fig. 6), and was lower

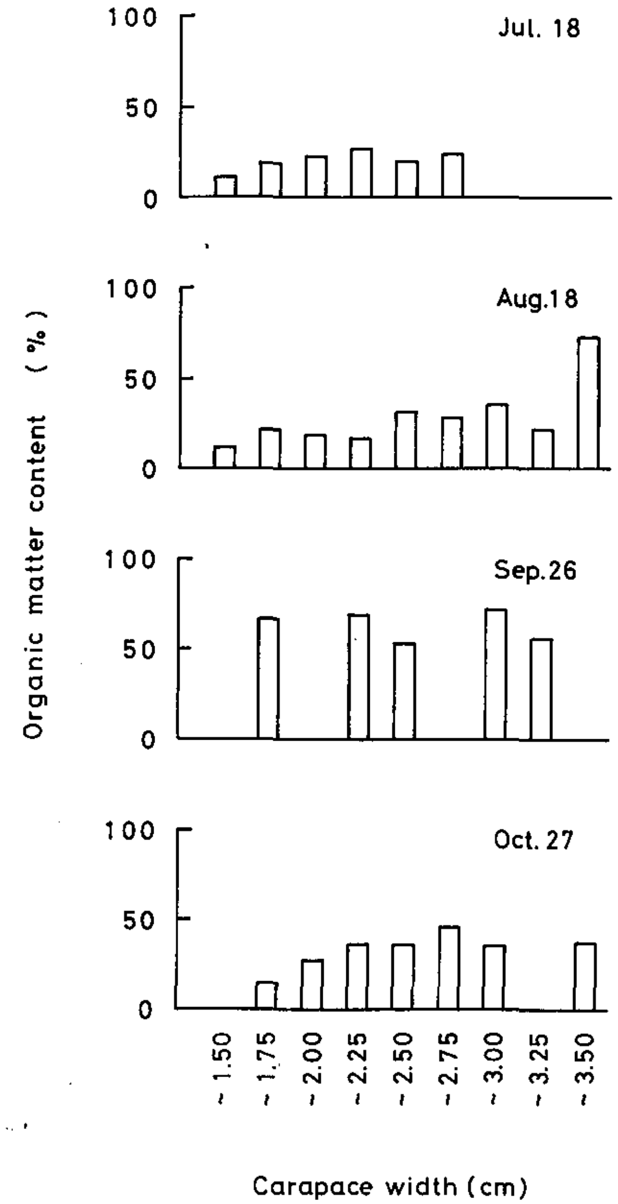

Fig. 5. Seasonal change in the organic matter component of the stomach content.

than that in the stomach contents throughout the study period. These results suggest that the mud crab fed selectively on organic matter in surface soil during the season with a low organic matter component in the stomach. During September, however, the high organic matter component in the stomach contents indicates that the crabs fed mainly upon other foods, such as plants and animals, because their

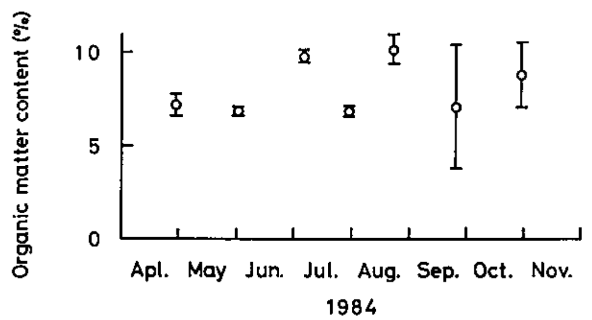

Fig. 6. Seasonal change in the organic matter content of the soil from the surface to a depth of 3 mm.

cheliped has no morphological feature suggesting that it can handle fine particles effectively and select fine organic matter in the soil (TAKEDA and KURIHARA, 1987a).

DISCUSSION

This study investigated the seasonal changes in feeding activity of the burrowing mud-crab, *Helice tridens*. The "stomach fullness" of a whole population was lowest in July, and then increased, reaching a maximum in October before winter, when activity ceased due to low temperatures (Fig. 1). Between June and September, large crabs could divided roughly into a group of individuals with high stomach fullness (between 81 and 100%) and a group of individuals with low contents (between 0 and 20% : Fig. 2). The former was thought to feed actively during low water, and the latter to act in other ways. The large male has been reported to wait for a female ready for copulation on the surface near each burrow during the period when exposed (BABA, 1978). In the present study area, the season of low stomach fullness corresponded with the copulation season, mainly from June to July. This suggests strongly that many large individuals participated in reproductive activity and that this caused the decrease in stomach fullness of the whole population.

On the other hand, stomach fullness reached a maximum in October. In winter, from November to May, the mud crab stays in its burrow. The increase in feeding activity during October may permit it to store energy to pass the winter. In addition, stomach fullness of the small crabs was higher than that of large ones throughout the investigation period (Fig. 1), indicating that small crabs spent more time for feeding activity than reproductive activity during the exposure period.

The organic matter component of stomach contents was low in July and August, and rapidly increased in September, but decreased again in October (Fig. 5). This indicates that food sources differ seasonally. The crabs were thought to feed in summer mainly upon fine organic matter and minerals in the surface soil. This hypothesis is supported by the observation that large mud-crabs relate strongly to their burrows during the copulation season (BABA, 1978), since they fed only in a very small area around each burrow. KURIHARA *et al.* (in preparation) have shown that the burrows protect small mud-crabs from predation by large ones, and that the small crabs are associated strongly with their burrows. These results indicate that small crabs feed mainly upon surface soil near each burrow, especially during the copulation season, because there are many large crabs on the surface.

Organic matter in stomach contents was clearly high in September as compared with other months (Fig. 5). This means that the mud crab fed mainly upon plants and animals immediately after the reproductive season, because the organic matter content of surface soil, which had been eaten in summer, was much lower than that of their stomach contents (Figs. 5 and 6). From summer to early fall, the mud crab was not associated strongly with its burrow (TAKEDA and KURIHARA, 1987b), and the large individuals wandered around the lagoon and creek in front of the salt marsh habitat (KURIHARA *et al.*, in preparation). The great increase in organic matter content in the stomach of large crabs was considered to reflect this wandering behaviour, since food organisms, such as fish, small ocypodid crabs and seaweed were abundant in the lagoon and creek. In addition, such movement of large crabs from the salt marsh habitat may decrease the likelihood that small crabs will be preyed upon by large ones, the interaction between individuals leading to a decrease in population density. These results may permit an increase in the home range of small crabs, and increase the chance that they encounter and feed upon plant and animal food.

In October, the organic matter component was lower than in September, suggesting that the crabs fed upon surface soil again. From fall to early winter, the grapsid crabs inhabit salt marsh dug burrows to pass the winter, and movement is restricted to the vicinity of burrows (HASHIGUCHI and MIYAKE, 1967). These observations fit in with the increase in the inorganic matter component in stomach contents during October.

The seasonal change in feeding activity of the fiddler crab, *Uca lactea*, has been investigated in the tidal flats of south Japan (YAMAGUCHI, 1970). Activity was high in the spring, then decreased in the summer, and increased again in the fall. The decrease in the summer was considered to be caused by reproductive behaviour, the season of which was from late June to mid August. Moreover, the increase in feeding activity in the fall was considered to be related to accumulation of energy in order to pass the winter. These conclusions provide further support for the above hypotheses about the influence of seasonal changes on the feeding activity of the grapsid crab, *H. tridens*.

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