Stomach Contents of the Southern Rough Shrimp *Trachysalambria curvirostris* (Stimpson) in the Coastal Area of Yeosu, Korea

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Abstract - **The southern rough shrimp *Trachysalambria curvirostris* (Stimpson) was monthly sampled from the coastal area of Yeosu, Korea from June 2000 to May 2001 and its stomach contents were investigated. Mysids and amphipods were the most dominant prey, comprising >40% of the diet in both % occurrence and % abundance. In particular, mysids were most important food without regard to seasons, size classes, or sexes. The abundance and occurrence composition of food items showed a seasonal fluctuation: mysids and amphipods were the predominant prey items in spring (33.8%), summer (41.1%), autumn (43.9%), and winter (49.2%). For small-sized shrimps (<25 mm CL), mysids and amphipods consist of more than 45% of its food in both % abundance and % occurrence. For large-sized shrimps (>25 mm CL), these were clearly dominant. The quantities and items of food did not differ in both genders, which mainly fed on mysids and amphipods. The trophic diversity and equality of diet varied with seasons and size classes. The diet diversity for smaller shrimps was highest in spring, while that for the larger shrimp lowest in winter. Also, the mandibular structure of *Trachysalambria curvirostris* indicates that the species is carnivorous.**

Key words : Stomach contents, Ecology, Statistical analysis, Shrimp, *Trachysalambria curvirostris*

INTRODUCTION

The penaeid prawns play ecologically important role as carnivore in marine environments. They feed on molluscs, crustaceans and aquatic insects (Chaitiamvong 1980; Marte 1980; Thomas 1980; Chong and Sasekumar 1981; Wassenberg and Hill 1987). Studies on their feeding habits showed that they are an ecologically important benthic predator (Evans 1983, 1984; Evans and Tallmark 1985; Reise 1978, 1985). In particular, the penaeid prawn *Penaeus indicus* mainly fed on crustaceans such as copepods, ostracods, amphipods, tiny decapods and their larvae and also molluscs, polychaetes, echinoderm larvae, hydroids, trematodes and foraminiferans were occasionally found (Mohamed 1970). Wassenberg and Hill (1987) reported that bivalves, gastropods, ophiuroids, crustaceans and polychaetes were the most abundant food items for juvenile and adult *P. esculentus* and *P. semisulcatus*. They suggested that differences in diets of the prawns could be attributed to differ in availability of particular foods. Hill and Wassenberg (1987) demonstrated that *P. esculentus* prefers crustaceans to bivalves as food if a choice is offered. Reymond and Lagardere (1990) reported that juvenile *P. japonicus* may be opportunistic carnivores, with a preference for macrobenthos and chironomids.

On the other hand, the southern rough shrimp, *Tra-*

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chysalambria curvirostris (Stimpson) (formerly known as *Trachypenaeus curvirostris*), known as a carnivorous nocturnal predator that buries in the sediment during the day (Kosaka 1979; Kim *et al.* 1984), occurs in the East China Sea and the coastal waters of Korea, Japan and China (Kubo 1949; Paulinose 1982). In particular, the species is locally abundant in the coastal areas of Korea (Kim 1977), because the sea off the southern and western coasts of Korea is relatively shallow (< 30 m) and provides highly suitable habitat for *Trachysalambria curvirostris* (Cha 1997; Kim 2002). Also, *T. curvirostris* is economically important aquatic resources in Korea, and most consumers prefer it to other penaeids. Despite its high abundance in bottom trawl catches and economic importance, its biology such as feeding habits is relatively little known.

The present study aims to provide understanding of some aspects in relation to the autecology of *T. curvirostris* in a benthic habitat. The insight on the composition and relative importance of food items from stomach content of *T. curvirostris* will provide greater understanding of its feeding strategy, life history process and role in ecosystem.

MATERIALS AND METHODS

1. Sampling

Trachysalambria curvirostris (Stimpson 1860) were collected in trawls in the vicinity of Sorido, off Yeosu (Southern Korea), at depths between 10 and 30 m (Fig. 1). Specimens of *T. curvirostris* were fixed in 4% neutralized formalin seawater, and after 24 h, stored in 70% alcohol. Samples were taken from June 2000 to May 2001 and data were seasonally compiled.

2. Laboratory analysis

All specimens were brought to the laboratory. Sex was determined by its morphological features and the carapace length (CL) were measured using Vernier callipers. Stomach contents of *T. curvirostris* were analyzed for 393 individuals, ranging from 10 to 35 mm in carapace length.

Stomach contents were examined under the stereo microscope (Olympus SZ-ILA) and the scanning electron microscope (SEM) (Hitachi S-3000N) and then identified to the lowest taxonomic category as possible. Before observation by SEM, stomach contents were dehydrated through a graded ethanol series and t-butyl alcohol and then dried by the critical point dryer (Hitachi HCP-2). The dried samples were mounted on stubs and coated with gold using the ion sputter (Hitachi E-1010).

Diets were seasonally determined: spring (March to May), summer (June to August), autumn (September to November) and winter (December to February). Specimens were classified by two sizes: small (< 25 mm CL) and large (> 25 mm CL). Also, the mandibular cutting edge were observed by SEM to verify the relationship between the morphology and the food items.

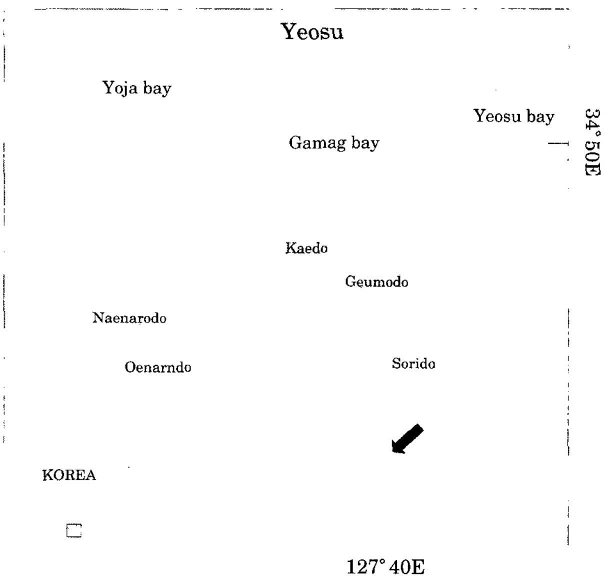

Fig. 1. Map of the sampling site in the coastal of Yeosu, southern Korea.

3. Data analysis

Numerous indices have been used for describing the importance of different prey in the diet of fish (Hynes 1950; Hyslop 1980). The percent frequency of occurrence (F) and relative abundance (A) for each type of prey were estimated by the following formulae:

$$\%F = (n_i/N) \times 100$$
$$\%A = (S_i/S_t) \times 100$$

where n_i is the number of shrimps with prey i in their stomach, N the total number of shrimps with stomach contents, S_i the number of prey i and S_t the total number of prey items.

Trophic diversity (H') in the diet for season and size class were calculated according to the Shannon-Wiener index (Cody and Diamond 1975):

$$H' = -\sum_{i=1}^{n} P_i \ln P_i$$

where P_i is the proportion of individuals in the i th species. Diet equality was also calculated for the different size classes and seasons, using Pielou's evenness index (Pielou 1975):

$$J' = H'(\text{observed})/H'_{max}$$

where is the maximum possible diversity which would be achieved if all foods were equally represented.

4. Statistical analysis

Some differences in the size-frequency distribution between males and females were determined by the Kolmogorov-Smirnov two-sample test (Sokal and Rohlf 1995) using SYSTAT Ver. 9.0. Contingency table analysis was employed to test for independence between prey types and season, size classes or sex. This statistical technique is simple and can readily identify the source of variation from columns and rows where appropriate when diets are expressed numerically or as occurrences

RESULTS

1. Size composition

Seasonal size distributions of the *Trachysalambria curvirostris* used for the analysis of diet are given in Fig. 2. A total of 393 individuals were investigated for this study: 91 specimens in spring, 105 specimens in summer, 110 specimens in autumn and 87 specimens in winter.

Statistical analysis revealed no significant difference in the size-frequency distribution between males and females (Kolmogorov-Smirnov two-sample test; d_{max} = 0.058, $P > 0.89$).

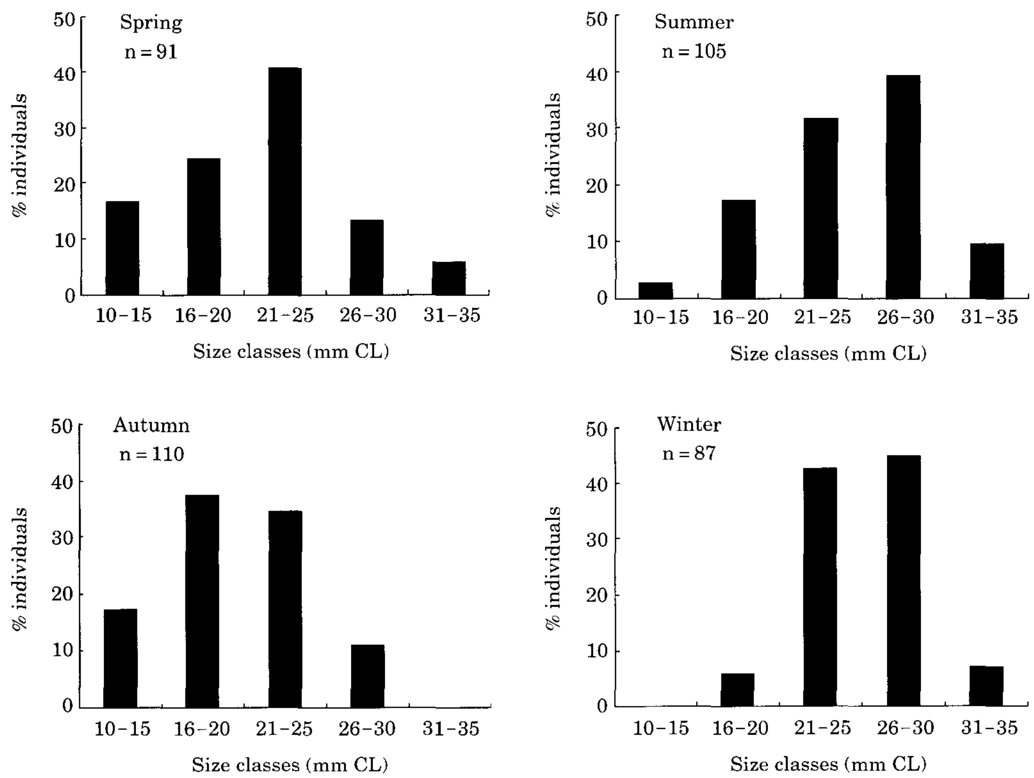

Fig. 2. Seasonal size structure of *Trachysalambria curvirostris* individuals examined for stomach contents analysis.

2. Diet composition and size classes

The most distinct components of the stomach contents of *Trachysalambria curvirostris* consisted of carapace or shells of crustaceans or molluscs, buccal parts, pleopods, mandibles of polychaetes, and calcified fragments of echinoderms, together with fish vertebrae.

Mysids and amphipods were the most important food items overall. These two categories accounted for over 40% of the diets (Table 1, Fig. 3). Molluscs and echinoids in the stomach contents occupied 8.3% and 7.0% of the total abundance of prey, respectively. The others inclu-

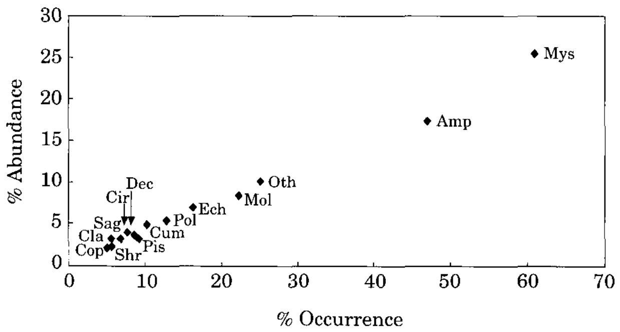

Fig. 3. Relative importance of overall diets: prey abundance plotted against frequency of occurrence of prey in the diet of *Trachysalambria curvirostris*. Values are calculated for pooled samples irrespective of seasons and size class (Amp, amphipods; Cir, cirripedia larvae; Cla, cladocera; Cop, copepoda; Cum, cumaceans; Dec, decapoda larvae; Ech, echinodermata; Mol, molluscs; Mys, mysids; Oth, others; Sag, saggita; Shr, shrimp; Pis, fish; Pol, polychaetes).

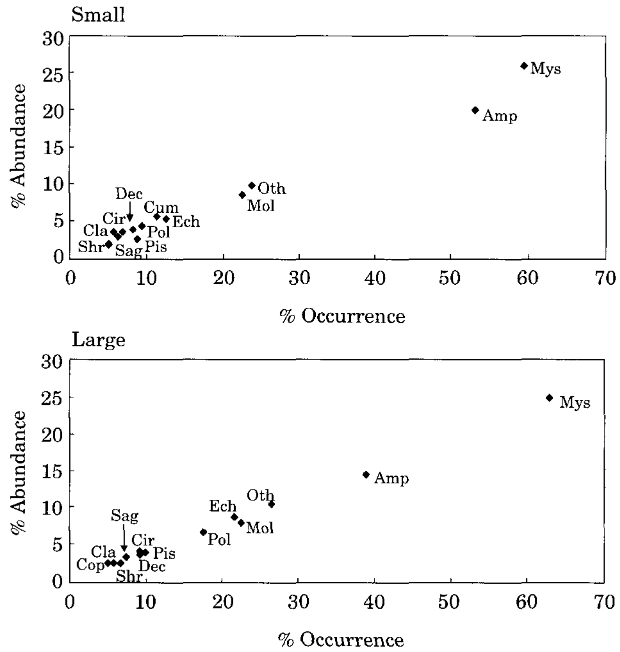

Fig. 4. Relative importance of overall diets: prey abundance plotted against frequency of occurrence of prey in the diet of *Trachysalambria curvirostris*. Values are calculated for samples combined by size class (Amp, amphipods; Cir, cirripedia larvae; Cla, cladocera; Cop, copepoda; Cum, cumaceans; Dec, decapoda larvae; Ech, echinodermata; Mol, molluscs; Mys, mysids; Oth, others; Sag, saggita; Shr, shrimp; Pis, fish; Pol, polychaetes).

Table 1. Diet composition of *Trachysalambria curvirostris* in the 4 seasonal groups and 2 size groups (%F, frequency of occurrence; %N, percentage abundance)

Season	Spring				Summer				Autumn				Winter			
Size class	Small		Large		Small		Large		Small		Large		Small		Large	
NO. examined	46		17		24		47		59		14		31		43	
Prey items	%F	%N	%F	%N	%F	%N	%F	%N	%F	%N	%F	%N	%F	%N	%F	%N
POLYCHAETA	13.0	6.3	23.5	6.3	4.2	3.0	14.9	4.6	10.2	4.4	21.4	7.7	6.5	3.6	16.3	8.4
CRUSTACEA																
Mysidacea	50.0	13.9	59.2	18.8	66.7	28.8	66	26.7	59.3	26.8	57.1	21.5	67.7	33.3	65.1	27.7
Amphipoda	58.7	19.0	41.2	16.7	54.2	18.2	36.2	11.5	47.5	19.7	35.7	15.4	54.8	22.6	41.9	16.8
Cumacea	10.9	3.8	11.8	4.2	8.3	4.5	8.5	3.1	13.6	6.6	7.1	4.6	9.7	6.0	9.3	5.0
Decapoda																
Shrimp	4.3	1.3	17.6	2.1	8.3	3.0	2.1	1.5	5.1	1.6	14.3	4.6	3.2	2.4	4.7	2.5
Decapoda larvae	2.2	2.5	–	–	8.3	3.0	6.4	2.3	5.1	2.2	7.1	3.1	3.2	2.4	2.3	1.7
Other crustaceans																
Cirripedia larvae	4.3	1.3	5.9	2.1	8.3	6.1	12.8	5.3	8.5	3.8	14.3	6.2	6.5	3.6	4.7	2.5
Cladocera	4.3	3.8	5.9	2.1	4.2	4.5	6.4	2.3	6.8	2.7	7.1	3.1	6.5	4.8	4.7	2.5
Copepoda	6.5	2.5	5.9	2.1	4.2	1.5	4.3	1.5	5.1	1.1	7.1	3.1	3.2	2.4	4.7	3.4
Crab postlarvae	6.5	1.3	11.8	4.2	–	–	8.5	3.1	5.1	2.7	–	–	–	–	–	–

ding foraminiferan, nematods, and algae comprised 10.1 % of the stomach contents.

Diet composition in the two size classes, small (< 25 mm CL) and large (> 25 mm CL), is shown in Fig. 4. For small-sized shrimps, more than 45% of food in both % abundance and % occurrence was accounted for by the combined mysids and amphipods. For large-sized shrimps, mysids and amphipods also were clearly dominant. The other categories contributed relatively minor proportions of the diet in both classes. In small, others and molluscs ranked as the third important prey items by % abundance and % occurrence, respectively. In large, others and molluscs ranked as the third and fourth important prey items in both % abundance and % occurrence. Comparisons were made to detect qualitative and quantitative differences in the diets of the various size classes, but the grand total x^2-values indicate no significant difference (df = 13, $p > 0.6$) in the proportions of prey types consumed by the two size classes (Table 3). The main source of variation comes mainly from mysids ($x^2 = 4.18$) and polychaetes ($x^2 = 2.81$).

3. Feeding and season

The abundance and occurrence composition of food items showed a seasonal fluctuation, but their trends were the same. Mysids and amphipods were the predominante prey items in spring (Fig. 5), when these two items combined accounted for over 33% of the diet according to both % abundance and % occurrence. Both indices highlighted their increasing importance through the year, dominating the diet in summer (41.1%), autumn (43.9%), and winter (49.2%).

The share of other prey items such as polychaetes declined, while echinoids increased in summer. A distinct shift in the diet began in summer, when the share of molluscs and others (foraminiferan, nematods, algae, unidentified materials) dropped from the spring values considerably. The grand total x^2-values indicate no significant difference (df = 39, $p > 0.4$) in the seasonal proportions of prey types consumed (Table 2). Among prey types, the main source of variation comes from molluscs ($x^2 = 17.05$) and amphipods ($x^2 = 6.98$), as demonstrated in the seasonal changes of prey items. Among seasons, the main source of variation come from spring ($x^2 = 19.98$).

4. Feeding and sex

The diets of males and females ate relatively similar

Table 2. Contingency table analysis of the seasonal variation of 14 different categories of food items found in the stomachs of *Trachysalambria curvirostris*. Values are total number of prey observed in each season, with expected values given in parenthesis. The x^2 test is not significant (*$P >$ 0.4)

Prey type	Spring	Summer	Autumn	Winter	N_i	x^2
Polychaeta	10(10)	8(9)	9(9)	9(8)	36	0.24
Mysidacea	34(35)	30(34)	33(33)	35(30)	132	1.23
Amphipoda	32(46)	47(44)	43(43)	49(39)	171	6.98
Cumacea	7(8)	6(7)	9(7)	7(7)	29	0.78
Shrimp	3(4)	4(4)	5(4)	4(4)	16	0.67
Decapoda larvae	6(6)	9(6)	7(6)	2(6)	24	3.77
Cirripedia larvae	4(4)	3(4)	4(4)	3(3)	14	0.19
Cladocera	5(4)	3(4)	5(4)	3(4)	16	0.77
Copepoda	3(6)	8(6)	7(6)	4(5)	22	3.06
Mollusca	31(17)	14(16)	10(16)	8(14)	63	17.05
Echinodermata	4(5)	6(5)	5(5)	4(4)	19	0.55
Saggita	13(12)	14(12)	11(12)	8(11)	46	1.10
Pisces	10(7)	4(7)	6(7)	6(6)	26	2.40
Others	21(19)	18(18)	17(18)	14(16)	70	0.53
N_i	183	174	171	156	684	
x^2	19.98	5.87	3.76	9.71		39.32*

Table 3. Contingency table analysis of the size class variation of 14 different categories of food items found in the stomachs of *Trachysalambria curvirostris*. Values are total number of prey observed in each size, with expected values given in parenthesis. The x^2 test is not significant (**$P >$ 0.6)

Prey type	Small	Large	N_i	x^2
Polychaeta	15(20)	21(16)	36	2.81
Mysidacea	85(73)	47(59)	132	4.18
Amphipoda	95(95)	76(76)	171	0.00
Cumacea	18(16)	11(13)	29	0.50
Shrimp	9(9)	7(7)	16	0.00
Decapoda larvae	13(13)	11(11)	24	0.02
Cirripedia larvae	8(8)	6(6)	14	0.01
Cladocera	8(9)	8(7)	16	0.2
Copepoda	11(12)	11(10)	22	0.28
Mollusca	36(35)	27(28)	63	0.07
Echinodermata	10(11)	9(8)	19	0.07
Saggita	20(26)	26(20)	46	2.72
Pisces	14(14)	12(12)	26	0.03
Others	38(39)	32(31)	70	0.05
N_i	380	304	684	
x^2	4.85	6.07		10.92**

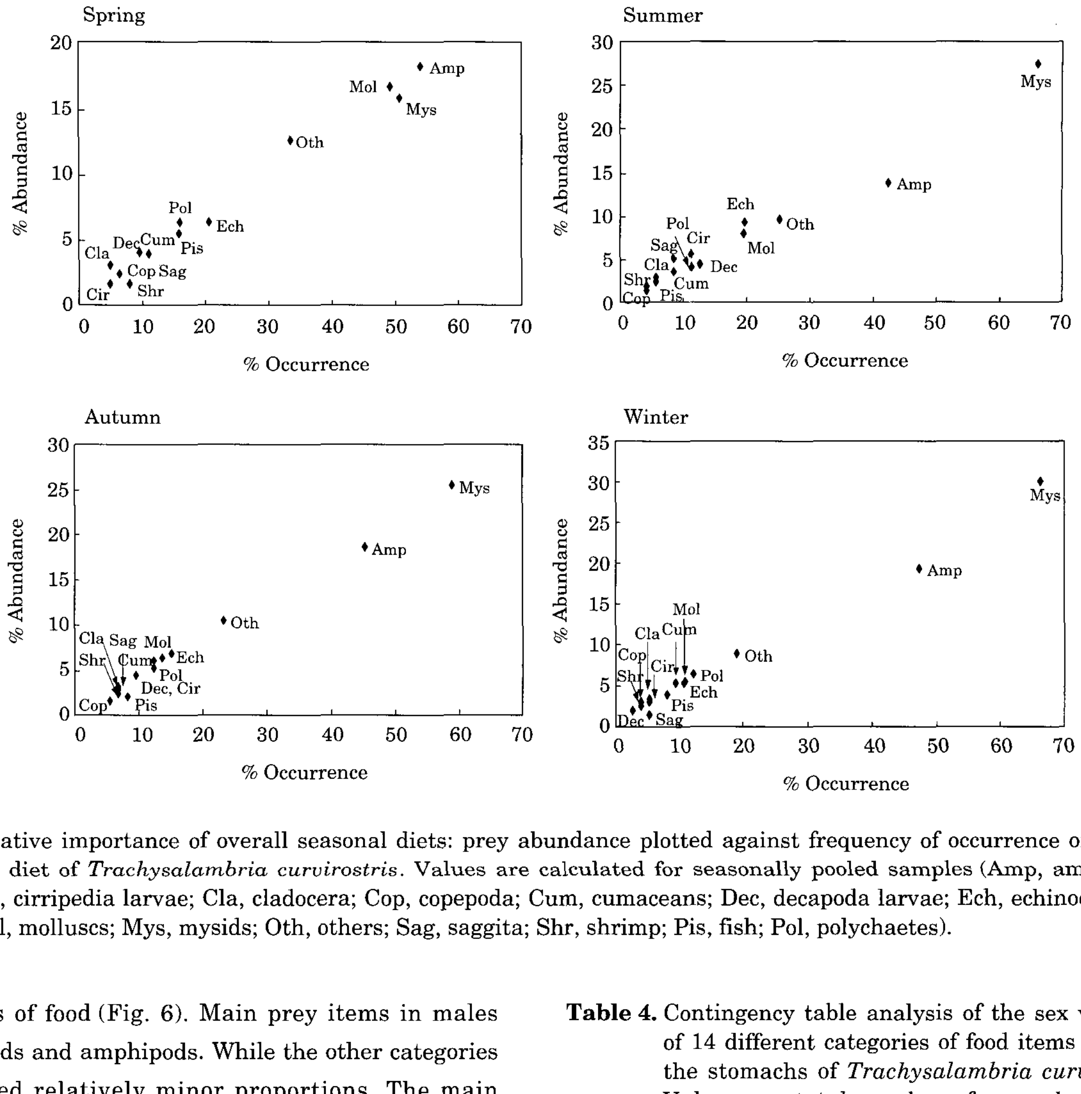

Fig. 5. Relative importance of overall seasonal diets: prey abundance plotted against frequency of occurrence of prey in the diet of *Trachysalambria curvirostris*. Values are calculated for seasonally pooled samples (Amp, amphipods; Cir, cirripedia larvae; Cla, cladocera; Cop, copepoda; Cum, cumaceans; Dec, decapoda larvae; Ech, echinodermata; Mol, molluscs; Mys, mysids; Oth, others; Sag, saggita; Shr, shrimp; Pis, fish; Pol, polychaetes).

quantities of food (Fig. 6). Main prey items in males were mysids and amphipods. While the other categories contributed relatively minor proportions. The main diets of females were similar to those of males but there were different in the importance of the other diets (Fig. 6).

Although the percent frequency of occurrence of all prey items was generally the same or higher in females as compared to males, the absolute abundance of each item was not quantitatively different for the two sexes. This was shown by means of a x^2-values, which yielded no significant difference (df = 13, $p > 0.9$) (Table 4).

5. Trophic diversity and equality

The trophic diversity and evenness for seasonal each size class are presented in Fig. 7. Diversity was observed to be generally low. Diversity for small shrimps was the highest in spring, while the lowest in winter. No

Table 4. Contingency table analysis of the sex variation of 14 different categories of food items found in the stomachs of *Trachysalambria curvirostris*. Values are total number of prey observed in each sex, with expected values given in parenthesis. The x^2 test is not significant (***$P > 0.9$)

Prey type	Male	Female	N_i	x^2
Polychaeta	22(19)	20(23)	42	0.79
Mysidacea	56(62)	79(74)	135	0.90
Amphipoda	90(90)	108(108)	198	0.00
Cumacea	20(17)	18(21)	38	0.77
Shrimp	11(11)	13(13)	24	0.00
Decapoda larvae	12(13)	17(16)	29	0.20
Cirripedia larvae	9(7)	7(9)	16	0.74
Cladocera	9(8)	8(9)	17	0.38
Copepoda	13(14)	17(16)	30	0.06
Mollusca	28(29)	36(35)	64	0.08
Echinodermata	11(11)	13(13)	24	0.00
Saggita	26(25)	28(29)	54	0.15
Pisces	11(11)	14(14)	25	0.02
Others	35(36)	44(43)	79	0.05
N_i	353	422	775	
x^2	2.25	1.89		4.14***

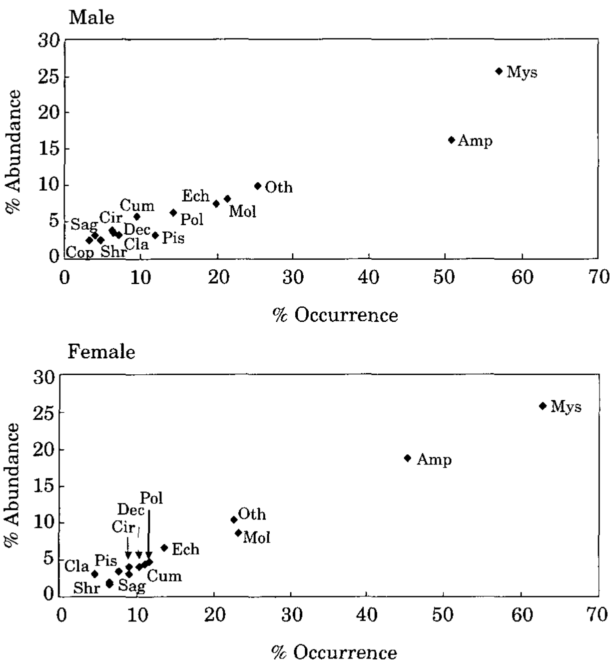

Fig. 6. Relative importance of overall diets: prey abundance plotted against frequency of occurrence of prey in the diet of *Trachysalambria curvirostris*. Values are calculated for samples combined by sex (Amp, amphipods; Cir, cirripedia larvae; Cla, cladocera; Cop, copepoda; Cum, cumaceans; Dec, decapoda larvae; Ech, echinodermata; Mol, molluscs; Mys, mysids; Oth, others; Sag, saggita; Shr, shrimp; Pis, fish; Pol, polychaetes).

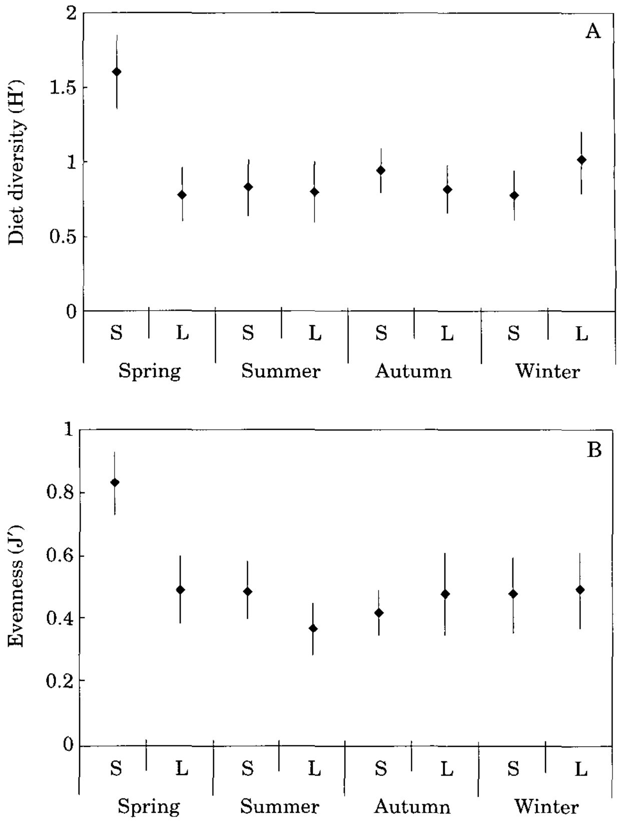

Fig. 7. Trophic diversity (A) and equality of prey items (B) found in small and large classes of *Trachysalambria curvirostris* at each season.

appreciable seasonal differences were observable between size classes. These trends were also similar for diet evenness (Fig. 7).

Both index values were higher in spring than in the other three seasons, indicating that the prey items consumed in spring were more evenly distributed, as demonstrated by the relative importance of seasonal diet composition.

6. Morphology

In order to integrate food preferences of *Trachysalambria curvirostris* with the structure of some organs involved in feeding, a morphological analysis was conducted using a scanning electron microscope (SEM). Mandibular cutting edges of the *T. curvirostris* are shown in Fig. 8. In *T. curvirostris* the mandibular structure has features typical of carnivorous species. In particular, the species has very developed mandibular cutting edges (Fig. 8A) and compared with its a small or degenerated molar tooth (Fig. 8B), indicating that it is adapted for cutting its animal foods.

DISCUSSION

The diet of *Trachysalambria curvirostris* consists entirely of benthic organisms and they can be divided into three main categories: (1) organisms that, as a result of vertical migrations, may dwell close to the bottom during part of the day (mysids, shrimps, fish, etc.); (2) organisms that, dwell on or just beneath the surface of the substratum (amphipods, gastropods, ophiuroids, etc.); (3) organisms that live completely or partially buried, digging out small galleries in the substratum (bivalves, cumaceans, polychaetes, etc.). This diet, although including a diversity of prey, was dominated in all seasons, size groups and sex by mysids and am-

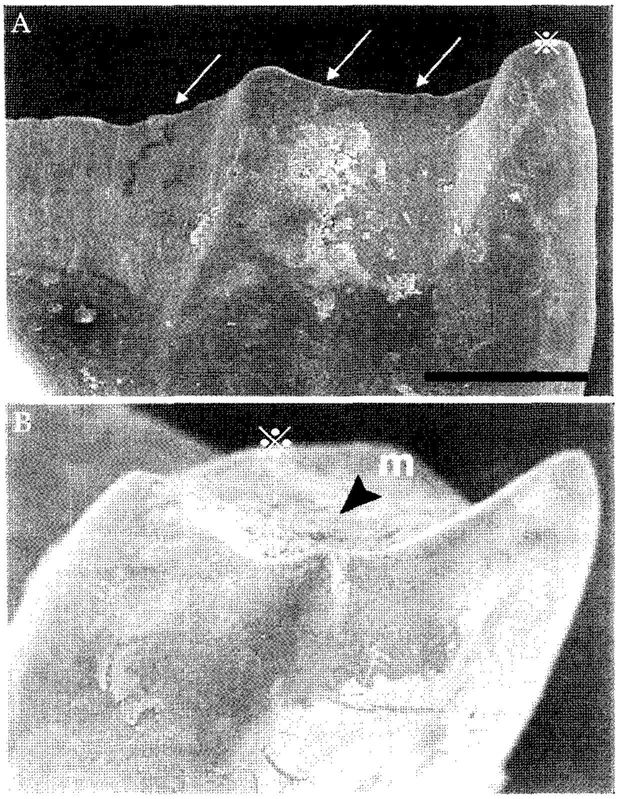

Fig. 8. *Trachysalambria curvirostris*. SEM pictures of mandibular cutting edge. In (A), the white arrows are indicating the mandibular cutting edge, ※: m, molar tooth. Scale = 500 μm

phipods. It is apparent that the shrimps have a particular preference for living food.

This carnivorous behaviour on bottom-dwelling organisms by *T. curvirostris* is a typical characteristic of penaeid shrimps. The most abundant food items found in small and large *T. curvirostris* were crustaceans and molluscs. These groups are also the main food for many species of penaeid, though the proportion of each food items was different. There are various factors affecting the penaeid stomach content such as tidal stage (Marte 1980; Wassenberg and Hill 1993), daylight, size of shrimp (Wassenberg and Hill 1987, 1993), sex (Marte 1980), moult stage (Hill and Wassenberg 1992), geographical location and availability of food items, seasonal change (Wassenberg and Hill 1987; Moriarty and Barclay 1981), prey/predator relative size (Reymond and Lagardere 1990) and shrimp preference (Wassenberg and Hill 1987; Hill and Wassenberg 1992). These food items were also reported in the foreguts of 31 species of penaeids, of 6 genera (*Metapenaeus, Metapenaeopsis, Penaeus, Parapenaeus, Solenocera, Trachypenaeus*) from the Indo-West Pacific (Hall 1962).

The diets of *Trachysalambria curvirostris* observed in this study are similar to those reported in other studies of this species, but there are also important differences. Our finding that *T. curvirostris* ate mainly crustaceans, molluscs and polychaetes was similar to the findings of other studies (Hall 1962; Kosaka 1979), while Kim *et al.* (1984) found that cephalopods were relatively major dietary item of *T. curvirostris* from Kogunsan in western Korea. The present study suggests that spatial variability in prey is the most important factors affecting changes in the dietary composition of *T. curvirostris*.

This is reported in other penaeid (Wassenberg and Hill 1993) and crangonid (Wahle 1985; Oh *et al.* 2001). No investigations dealing with spatial variations in benthic community structure in the study area are known. Spatial differences in the diet of *T. curvirostris* are related to differences in habitats, particularly in substrate type, which would determine the abundance and structure of the different community of potential prey.

Trophic diversity did not be researched between seasonal size classes, but the diversity may exhibit seasonal variations because of the difference of seasonal foods. The highest values were observed in spring, a likely consequence of the substantial increase in the availability of prey items, while the lowest values in autumn were observed as a result of reduction in the range of prey items. Another possible explanation might be attributed to the changes of prey abundance associated with seasonal variations of primary production.

The anatomy of this species shows a compromise between herbivorous and carnivorous morphological features (Fig. 7). The SEM pictures clearly show that the *T. curvirostris* mandibular has the cutting edges typical of many presumed carnivorous species of its homogeneity. These mandibular cutting edges are considered to be good tools for cutting food animals such as crustaceans and polychaetes. In the diet of *T. curvirostris*, such as the decrease in occurrence of herbivorous prey items like algae, may reflect changes in the ability of shrimps to manipulate herbivorous prey. This indicates that the morphological characteristics of the molar tooth is usually assumed to degenerative in *T. curvirostris*.

In conclusion, exploitation of food items by the southern rough shrimp *T. curvirostris* revealed no significant differences in diet between the various season, size classes and sexes. Also, there were a positive correlation between the frequency of occurrence of food items in the foregut of the *T. curvirostris* and the predominant groups of the benthic community. However, to verify food preference of *T. curvirostris* further studies are needed to detect the seasonal variation of benthic community structure for this study area.

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REFERENCES

Cha HK. 1997. Ecology of *Metapenaeus joyneri* Miers and *Trachypenaeus curvirostris* Stimpson (Decapoda: Penaeidae) in the western coast of Korea. Ph.D. Thesis, National Fisheries University of Pusan. Korea. 150pp. (in Korean, with English abstract)

Chaitiamvong S. 1980. The biology of penaeid shrimps of Thailand. In: Report of the workshop on the Biology and Resources of Penaeid Shrimps in the South China Sea Area-Part 1. During 30 June-5 July 1980, held at Kota Kinabulu, Sabah, Malaysia. pp. 64-69. FAO/ UNDP. Manila, Philippines.

Chong VC and A Sasekumar. 1981. Food and feeding habits of the white prawn *Penaeus merguiensis*. Mar. Ecol. Prog. Ser. 5:185-191.

Cody ML and JM Diamond. 1975. Ecology and evolution of communities. The Belknap Harvard University Press. London. 545pp.

Dall W. 1968. Food and feeding of some Australian penaeid shrimps. FAO Fish. Rep. Ser. 57:251-258.

Evans S. 1983. Production, predation and food niche segregation in a marine soft bottom communtiy. Mar. Ecol. Prog. Ser. 10:147-157.

Evans S. 1984. Energy budgets and predation impact of dominant epibenthic carnivores on a shallow soft bottom community at the Swedish west coast. Estuar. Coast. shelf. Sci. 18:651-672.

Evans S and B Tallmark. 1985. Niche separation within the mobile predator guild on marine shallow soft bottom. Mar. Ecol. Prog. Ser. 23:279-286.

Hall DNF. 1962. Observations on the taxonomy and biology of some Indo-West-Pacific penaeidae (Crustacea: Decapoda). Colonial Office Fishery Publications No. 17. Her Majesty Stationery Office. London.

Hill BJ and TJ Wassenberg. 1987. Feeding behaviour of adult tiger prawns, *Penaeus esculentus* under laboratory conditions. Austr. J. Mar. Freshw. Res. 38:183-190.

Hill BJ and TJ Wassenberg. 1992. Preferences and amount of food eaten by the prawn *penaeus esculentus* over the moult cycle. Austr. J. Mar. Freshw. Res. 43:727-735.

Hynes HBN. 1950. The food fo fresh-water sticklebacks (*Gasterosteus aculeatus* and *Pygosteus pungitus*), with a review of methods used in studies of the food of fish-es. J. Anim. Ecol. 19:36-58.

Hyslop EJ. 1980. Stomach contents analysis-a review of methods and their application. J. Fish. Biol. 17:411-429.

Kim DW. 2002. A study of shrimps composition and ecology in around coast Yosu. M.S. Thesis, Yosu Nat. Univ. Yeosu. 38pp. (in Korean, with English abstract)

Kim HS. 1977. Illustrated Flora and Fauna of Korea, Samwha Publishing Co, 19. 694pp.

Kim YH, SD Lee and BG Kim. 1984. Ecological study on the shrimp, *Trachypenaeus curvirostris*. Bull. Fish. Res. Dev. Agency. 32:25-30. (in Korean, with English abstract)

Kosaka M. 1979. Ecological notes on the penaeid shrimp, *Trachypenaeus curvirostris* (Stimpson) in Sendai Bay. Bull. Fac. Fish. Tokai. Univ. 12:167-172.

Kubo. 1949. Studies on the penaeids of Japanese and its adjacent waters. J. Tokyo Coll. Fish. 36(1):393-398.

Marte CL. 1980. The food and feeding habit of *Penaeus monodon* Fabricius collected from Makato River, Aklan, Philippines (Decapoda: Natantis). Crustaceana 38:225-236.

Mohamed KH. 1970. Synopsis of biological data on the Indian prawn *Penaeus indicus* H. Milne Edwards, 1837. FAO Fish. Rep. 57(4):1267-1288.

Moriarty DJW and MC Barclay. 1981. Carbon and nitrogen content of food and the assimilation efficiencies of penaeid prawns in the Gulf of Carpentaria. Austr. J. Mar. Freshw. Res. 32:245-251.

Oh CW, RG Hartnoll and RDM Nash. 2001. Feeding ecology of the common shrimp *Crangon crangon* in Port Erin Bay, Isle of Man, Irish Sea. Mar. Ecol. Prog. Ser.

214:211-223.

Paulinose VT. 1982. Decapod Crustacea form the international Indian Ocean Expedition. Larval and postlarval stages of *Trachypenaeus curvirostris* (Stimpson). J. Nat. Hist. 16:663-672.

Pielou EC. 1975. Ecological diversity. Wiley, New York.

Reise K. 1978. Experiments on epibenthic predation in the Wadden Sea. Helgol Wiss Meeresunters. 31:55-101.

Reise K. 1985. Tidal flat ecology. An experimental approach to species interaction. Springer-Verlag, Berlin.

Reymond H and JP Lagardere. 1990. Feeding rhythms and food of *Penaeus japonicus* Bate (Crustacea: Penaeidae) in salt marsh ponds: role of halophilic entomofauna. Aquaculture 84:125-143.

Sokal RR and FJ Rohlf. 1995. Biometry. WH Freeman & Co. New York.

Thomas MM. 1980. Food and feeding habits of *Penaeus semisulcatus* de Haan at Mandapam. India. J. Fish. 27: 130-139.

Wahle RA. 1985. The feeding ecology of *Crangon franciscorum* and *Crangon nigricauda* in San Francisco Bay, California. J. Crust. Biol. 5:311-326.

Wassenberg TJ and BJ Hill. 1987. Natural diet of the tiger prawns *Penaeus esculentus* and *P. semisulcatus*. Aust. J. Mar. Freshw. Res. 38:169-182.

Wassenberg TJ and BJ Hill. 1993. Diet and feeding behaviour of Juvenile and adult banana prawns *Penaeus merguiensis* in the Gulf of Carpentaria, Austr. Mar. Ecol. Prog. Series. 94:287-295.

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