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Feeding Ecology of *Sillago japonica* in an Eelgrass (*Zostera marina*) Bed

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Feeding habits of *Sillago japonica* collected from in an eelgrass (*Zostera marina*) bed in Jindong Bay, Korea were studied. *S. japonica* was a carnivore which consumed mainly gammarid amphipods, polychaetes, bivalves, caridean shrimps and crabs. Its diets also included a small amount of fishes, copepods and caprellid amphipods. The diet of *S. japonica* underwent significant size-related changes; small individuals (<5 cm SL) fed mainly on gammarid amphipods and crab larvae, while proportion of polychaetes and bivalves increased with increasing fish size and gammarid amphipods were also important prey for medium size individuals (5.1-9.9 cm SL). The large individuals (>10 cm SL) ate polychaetes, caridean shrimps and crabs. The dietary breadth of *S. japonica* were varied with size. The diet of *S. japonica* also underwent seasonal changes that could be related to differences in prey availability; gammarid amphipods were mainly consumed in spring and polychaetes in summer.

Key words: *Sillago japonica*, Feeding habits, Eelgrass bed, Gammarid amphipods, Dietary breadth index

Introduction

Sillago japonica (Family Sillaginidae) is widely distributed in sandy habitat along coastline of Korea and use eelgrass (*Zostera marina*) bed as nursery area (Huh and Kwak, 1997a, Kim and Kang, 1993). Despite their high abundance in an eelgrass bed, little has been known on the feeding ecology of *S. japonica* in Korean seagrass bed.

The feeding habits of sillaginid species have been studied in the other waters. For example, Kwak et al. (2001) found that *S. maculata*, a congener of *S. japonica*, consumed mainly gammarid amphipods and crab larvae in the tropical seagrass beds and amphipods and decapods as a major prey for the *Sillaginodes punctatus* in the temperate seagrass beds, Weatern Port, Australia (Robertson, 1977; Edgar and Shaw, 1995; Jenkins and Wheatley, 1998). On the other hand, crustaceans and small fishes made the greatest contributions to the stomach contents of sillaginid species (*S. bassensis*, *S. vittata*, *S. burrus*, *S. schomburgkii*, *S. robusta*, *S. punctatus*) in coastal waters, Australia (Hyndes et al. 1997).

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The aim of this study is to investigate feeding ecology of *S. japonica* in an eelgrass bed of Jindong Bay and to determine the overall diet of *S. japonica*, the size-related and seasonal changes in feeding habits.

Materials and Methods

The sampling was carried out in an eelgrass (Zostera marina) bed in Jindong Bay, Korea (35°06'N, 128° 32'E). *Z. marina* was forming subtidal bands (500-700 m wide) in the shallow water (<3 m) along the shoreline of Jindong Bay.

S. japonica were collected monthly with 5 m otter trawl (1.9 cm mesh wing and body; 0.6 cm mesh liner) throughout 2002. Stomachs of fish were preserved immediately in 10% formaline, and length and weight of each fish were measured. Stomach contents were removed and transferred to 70% iso-propanol for storage. Gut contents from each fish were identified and occurrence, number of individuals and dry weight of each prey species were recorded.

Dietary breadth index was calculated using Levins standardized index (Krebs, 1989):

$$B_i=1/n-1(1/\sum_j P_{ij}^2-1)$$

Where Bi_i=Levins standardized index for predator *i*, P_{ij}=proportion of diet of predator *i* that is made up of prey *j*, and n=number of prey categories. This index ranges from 0 to 1, with low values indicating diets dominated by a few prey items (specialist predators) and high values indicating generalist diets (Gibson and Ezzi, 1987; Krebs, 1989).

Results and Discussion

Size distribution

S. japonica was collected in an eelgrass bed from March to December 2002 (Fig. 1). Size range was

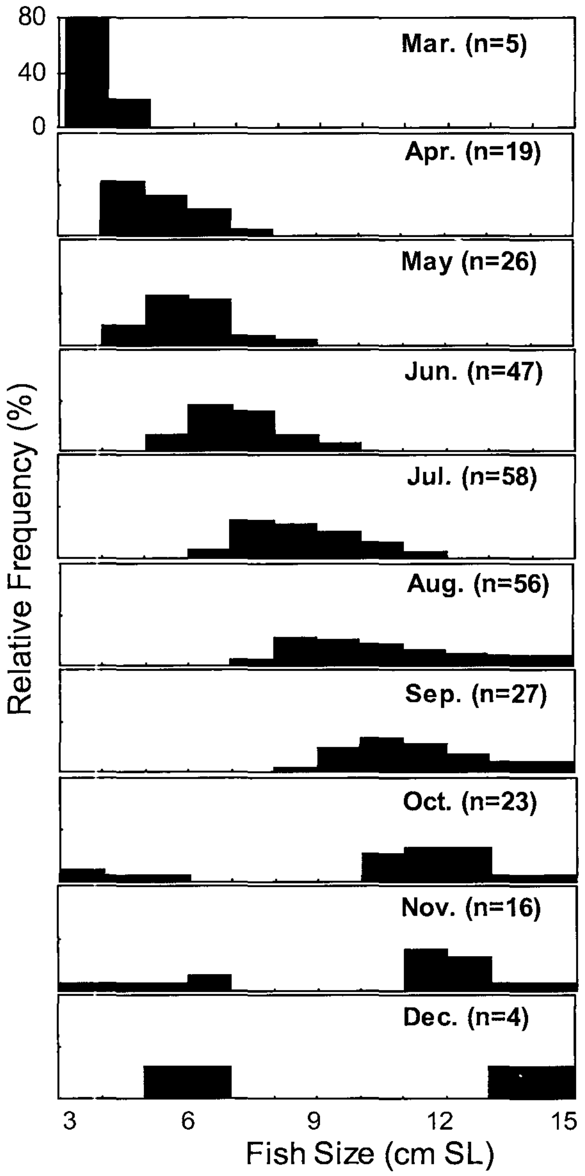

Fig. 1. Monthly variation in size distributions of *Sillago japonica*.

3.3-14.7 cm SL during the study period. Small individuals (<5 cm SL) first appeared as in March 2002 and remained in the study area until December 2002 size ranged from 5.4-14.5 cm SL. Number of individuals were small in March and April 2002, peaked in July and August 2002 and then declined to minimum in December 2002.

Stomach contents analysis

A total of 281 stomachs were examined, of which 28 (10.0%) were empty. The stomachs contained 29 identifiable prey components (Table 1). Gammarid amphipods were the most important prey group for *S. japonica*, comprising 31.7% of the diet by dry weight, 50.7% of the diet by number and occurring in 53.6% of all stomachs examined. *Ampithoe* sp., *Ericthonius* sp. and *Leucothoe* sp. were the principal genera of gammarid amphipods consumed. After gammarid amphipods, polychaetes were second in importance, comprising 25.8% of the diet by weight, 12.7% of the diet by number and 48.7% of the diet by occurrence. *Platynereis bicanaliculata*, *Lumbrineris* sp. and *Cirratulus* sp. were the principal prey items. Bivalves and caridean shrimps were the next important dietary components, comprising 12.8%, 12.6% of the diet by dry weight. The siphon of bivalves was common prey items, and the caridean shrimps *Crangon affinis* and *Alpheus digitalis* were the principal prey group. Brachyurans were a frequent group, accounting for 11.8% of the diet by dry weight. Crab larvae (zoea and megalopa stages) were mainly consumed by smaller individuals, whereas *Hemigrapsus penicillatus* were fed by larger individuals. Small fishes and copepods were of little importance, comprising 2.4%, 1.7% of the diet by dry weight, respectively. Caprellid amphipods, isopods and tanaids are negligible.

Variations in stomach contents in relation to fish size

Relationships between relative prey composition and body length of *S. japonica* were presented in Fig. 2. Small *S. japonica* (<5 cm SL) fed mainly on gammarid amphipods and crab larvae. The portion of the diet attributable to crab larvae decreased gradually with increasing size, while proportion of polychaetes and bivalves increased. Consumption of gammarid amphipods by *S. japonica* was relatively constant (34.1-41.3%) in the medium size (5.1-9.9 cm SL). The large fish (>10 cm SL) ate a wide range of prey including polychaetes, caridean shrimps and

Table 1. Percent composition of the stomach contents of *Sillago japonica* by frequency of occurrence, number and dry weight

Food organisms	Occurrence (%)	Number (%)	Dry weight (%)
Crustacea			
Amphipoda			
Gammaridea	**53.6**	**50.7**	**31.7**
Ampithoe sp.	25.5	14.6	9.8
Ericthonius sp.	23.1	10.1	5.9
Leucothoe sp.	20.6	9.9	6.0
Elasmopus sp.	19.8	8.7	5.2
Ampelisca sp.	17.5	7.4	4.8
Caprellidea	**8.9**	**2.5**	**1.1**
Caprella kroeyeri	7.6	1.4	0.6
Caprella tsugarensis	4.4	1.1	0.5
Decapoda			
Caridea	**25.8**	**5.1**	**12.6**
Crangon affinis	10.8	1.7	3.8
Alpheus digitalis	6.6	1.1	3.4
Latreus anoplonyx	5.4	0.9	2.3
Palaemon macrodactylus	4.5	0.8	1.9
Eualus leptognathus	3.9	0.6	1.2
Brachyura	**26.6**	**8.6**	**11.8**
Hemigrapsus penicillatus	9.9	1.7	5.3
Crab larvae (zoea)	13.5	3.8	3.6
Crab larvae (megalopa)	10.1	3.1	2.9
Copepoda	**22.5**	**13.2**	**1.7**
Calanus sinicus	25.9	5.6	0.7
Centropages yamadai	15.6	4.5	0.6
Oncaea sp.	15.3	3.1	0.4
Isopoda			
Cymodoce japonicus	0.6	0.1	0.1
Tanaidacea			
Tanais cavolinii	1.4	0.3	0.1
Polychaeta	**48.7**	**12.7**	**25.8**
Platynereis bicanaliculata	19.7	3.1	7.1
Lumbrineris sp.	18.7	3.1	6.8
Cirratulus sp.	15.6	2.3	4.5
Capitella sp.	13.3	2.1	3.8
Unidentified	12.1	2.1	3.6
Mollusca			
Bivalvia	**19.8**	**6.4**	**12.8**
Pisces	**1.1**	**0.3**	**2.4**
Acanthogobius flavimanus	0.5	0.1	0.8
Acentrogobius pflaumi	0.4	0.1	0.8
Platycephalus indicus	0.1	0.1	0.8
Total		100	100

crabs. *S. japonica* fed also on larger sizes of prey with increasing size (Fig. 3). *S. japonica* consumed mainly on a wide range size of gammarid amphipods in all size classes, and larger fish more than 7 cm SL fed on larger gammarid amphipods (8.8-15.5 mm, mean length). In the case of *C. affinis* and *H. penicillatus*, larger fish fed on larger prey size (2.4-4.1 mm and 5.7-6.7 mm, mean length).

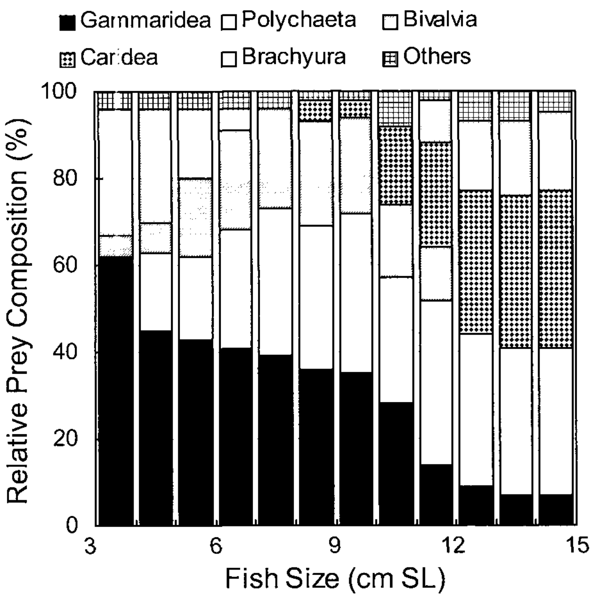

Fig. 2. Relationships between relative prey composition (DW, %) and body length of *Sillago japonica*.

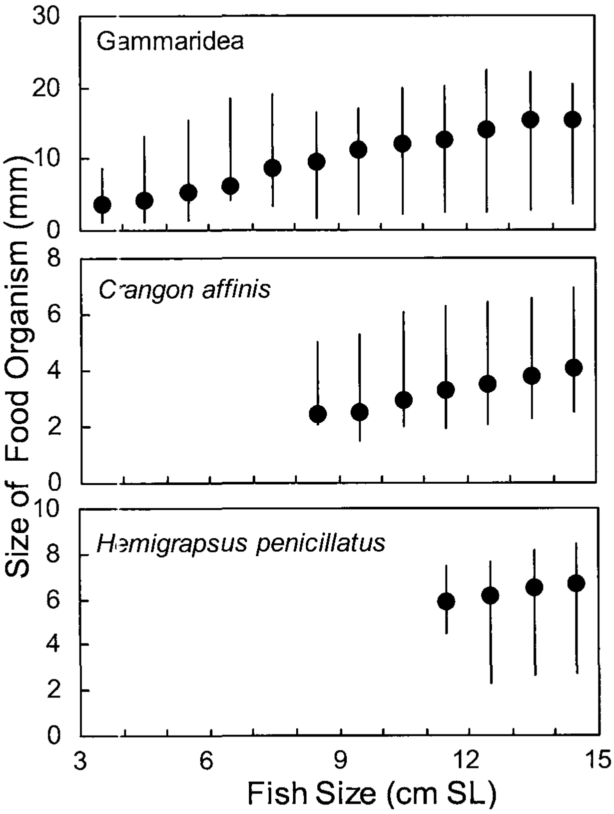

Fig. 3. Relationships between size of food organisms and body length of *Sillago japonica* (total length for Gammaridea, carapace length for *Crangon affinis* and carapace width for *Hemigrapsus penicillatus*). Solid circle and vertical bar represent the mean and range, respectively.

Dietary breadth of *S. japonica* varied with fish size (Fig. 4). The low dietary breadth of small *S. japonica* increased to a maximum value at 10-11 cm SL, however, this value decreased with larger fish size.

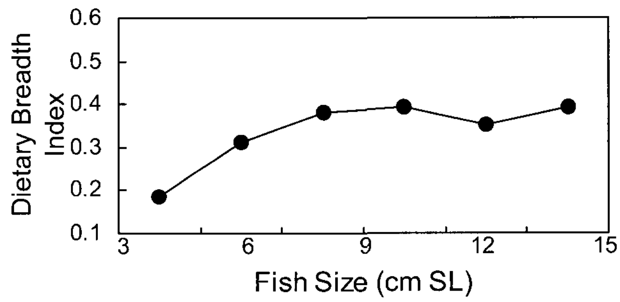

Fig. 4. The size-related variations of dietary breadth index of *Sillago japonica*.

Dietary composition of sillaginid species undergoes a similar type of size-related changes in the seagrass beds throughout worldwide. These changes involve a dietary shift from small prey species such as amphipods (gammarid amphipods and caprellids amphipods) by small fishes to large prey species such as polychaetes, caridean shrimps and crabs. Domination by gammarid amphipods in the diet of the small *S. japonica* parallelled the reports of the diet of *S. maculata* in the tropical seagrass beds and *S. punctatus* at Western Port, Victoria, Australia (Robertson, 1977; Edgar and Shaw, 1995; Kwak et al., 2001). Likewise, small *S. punctatus* consumed amphipods and copepods, while large individuals fed on polychaetes and decapods in a southern Australian embayment (Jenkins and Wheatley, 1998). On the other hand, smaller sillaginid species (*S. bassensis*, *S. vittata*, *S. burrus*, *S. schomburgkii*, *S. robusta*, *S. punctatus*) fed mainly on copepods and cumaceans, whereas larger individuals consumed on stomatopods and small fishes in coastal waters in Australia (Hyndes et al. 1997). This results was largely related to the similar composition of prey animals in the seagrass beds regardless of location and climate. For example, gammarid amphipods were abundant groups on the blade of seagrass and polychaetes, caridean shrimps and crabs typically inhabiting the leaf substratum in the seagrass beds throughout the world (Stoner, 1980, 1983; Edgar, 1992; Gambi et al., 1992; Knowles and Bell, 1998; Kwak, unpublished data).

Seasonal changes in food habits

Feeding habits of *S. japonica* varied with season

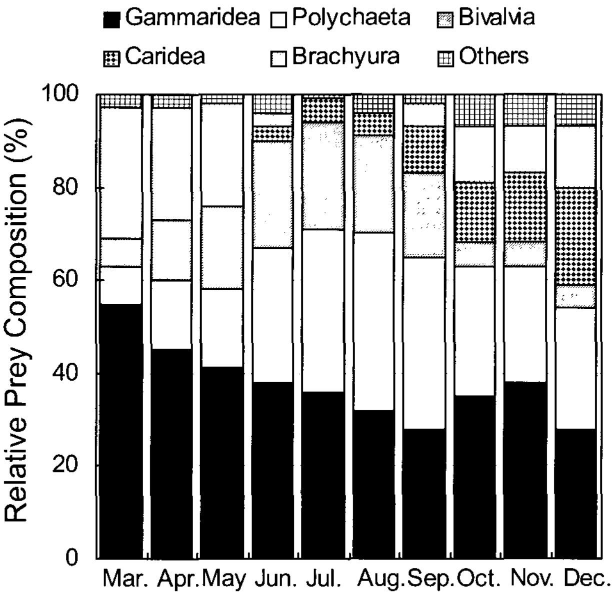

Fig. 5. Seasonal changes in relative prey composition (DW, %) of the diet of *Sillago japonica.*

(Fig. 5). Gammarid amphipods and crab larvae were important prey from March to May 2002, however, gammarid amphipods, polychaetes and bivalves were from June to September 2002. Proportion of bivalves declined sharply to a 5% of the diet of dry weight, and a wide range of prey, including polychaetes, caridean shrimps, crab, and bivalves were consumed by *S. japonica* in the remaining periods. These changes occur as a gradual alteration in proportion of food types and the addition of new prey type with season, which is a general trend in the feeding of fishes (*Syngnathus schlegeli*, *Pholis nebulosa*, *Acentrogobius pflaumii* and *Favonigobius gymnauchen*) in the eelgrass beds (Huh and Kwak, 1997b,c, 1998a,b).

Seasonal changes in diet of *S. japonica* can be attributed to either selective preference by the predator or abundance and availability of prey species. Amphipods, polychaetes and crab larvae were abundant prey items throughout the year with some seasonal changes occurring in the relative proportion of each. For example, high abundance of gammarid amphipods was during spring and summer, which is the period of seagrass growth and high water temperature in an eelgrass bed. Caridean shrimps and crabs abundance appeared to be greater April, May and from September to November 2002 and peak abundance of polychaetes were during summer and fall (Kwak, unpublished data). Thus, data on both the effect of seagrass growth and the activity of predator and prey on abundance and availability of prey species would be useful in explaining these seasonal trends in feeding habits of *S. japonica.*

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