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Diel Changes in the Diet of *Rudarius ercodes*: A Diurnal Omnivore and Nocturnal Carnivore

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Diel changes in the feeding habits of *Rudarius ercodes* were investigated in an eelgrass bed of Jindong Bay, Korea. The main food components for *R. ercodes* (1.6～4.3 cm SL) were gammarid amphipods, eelgrass, polychaetes and urochordates. Most dietary items were inhabitants of an eelgrass bed. Diel variations in diet and feeding activity occurred. The diet of *R. ercodes* underwent changes from eelgrass and gammarid amphipods (omnivore) at day to mainly gammarid amphipods, polychaetes, and urochordates (carnivore) at night. *Rudarius ercodes* probably took detached eelgrass leaves and grazed live eelgrass during day, whereas feeding on gammarid amphipods, polychaetes, urochordates, and bivalves were facilitated by nocturnal movement and activity of these prey during night. The feeding activity of *R. ercodes* was also correlated with periods of high tides.

Key words : *Rudarius ercodes*, diel, diet, gammarid amphipods, eelgrass, polychaetes, urochordates, tide

Introduction

The eelgrass (*Zostera marina*) beds is very important as rich, productive nursery and feeding area for juvenile and adult fishes (Adams, 1976; Pollard, 1984; Klumpp *et al*., 1989; Hemminga and Duarte, 2000). The eelgrass beds of Jindong Bay, Korea, provide a habitat for variety of invertebrates and small fish, which in turn are the potential food of significant fisheries. In particular, *Rudarius ercodes* (family Monacanthidae) is one of the most abundant in the study area, and it is also an important common fish species in several areas (Huh and Kwak, 1997; Lee *et al*., 2000).

To date of the feeding habits of monacanthid fish species, *Rudarius ercodes* and *Stephanolepis cirrhifer*, suggested that it is a omnivore, feeding primarily amphipods (gammarids and caprellids) and eelgrass (Kwak *et al*., 2003; Kwak and Huh, 2004). Worldwide, the members of family Monacanthidae are associated with shallow water seagrass beds, and seagrass tissue forms major portion of their diets (e.g. Randall, 1967; Bell *et al*., 1978). On the other hand, Horinouchi *et al*. (1998) recorded that caprellid amphipods and polychaetes as a major prey for the *R. ercodes* and Kikuchi (1974) found that monacanthid fish species in Japan fed on bryozoan and polychaetes. These studies indicated that the diets of monacanthid fish species are extremely diverse and opportunistic feeders.

As a first step to understanding the feeding habits of *R. ercodes*, this study deals with its natural diet, emphasizing diel dietary shifts and relationship between fish size and diet. The study shows that the feeding strategy of *R.*

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ercodes is more complex than previously reported.

Materials and Methods

All the sampling was carried out in an eelgrass (*Zostera marina*) bed in Jindong Bay, Korea (35° 06′N, 128°32′E, Fig. 1). *Zostera marina* was forming subtidal bands (500～700 m wide) in the shallow water (< 3 m) along the shoreline of Jindong Bay.

Rudarius ercodes collected with 5 m otter trawl (1.9 cm mesh wing and body, 0.6 cm mesh liner) in an eelgrass bed. Three or Four 6-min tows were taken as serial samples (every 3 h over 24-h period). Two serial sampling were made, the first session on 12～13 September 2001 (last quarter moon) and second session on 19～20 September 2001 (new moon) as part of a large study of the feeding habits of fish associated with an eelgrass bed.

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% isopropanol 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):

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

Where B_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). In order to describe the feeding activity, the fullness index (total weight stomach contents × 100/total body weight) was recorded.

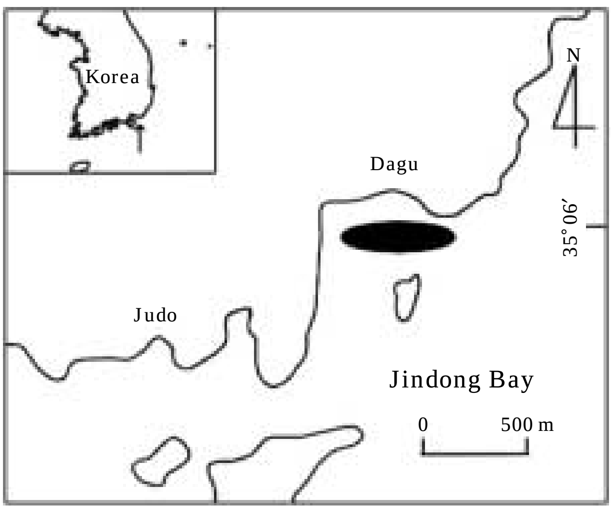

Fig. 1. Location of the study area (the black area) in Jindong Bay, Korea.

Results and Discussion

Size distribution

The size distribution of all *R. ercodes* collected in an eelgrass bed was similar for day and night samples (Fig. 2). Size range of *R. ercodes* was 1.6～4.3 cm SL and most of individuals were 2.1～2.9 cm SL during study period. On the other hand, number of individuals were higher value at night than those of at day.

Stomach contents analysis

There was a clear diel change in the diet of *R. ercodes* (Table 1). During the day, eelgrass was the most important prey group for *R. ercodes*, comprising 47.8% of the diet by dry weight and occurring in 77.5% of all stomachs examined. After eelgrass, gammarid amphipods were secondary in importance, comprising 31.3% of the

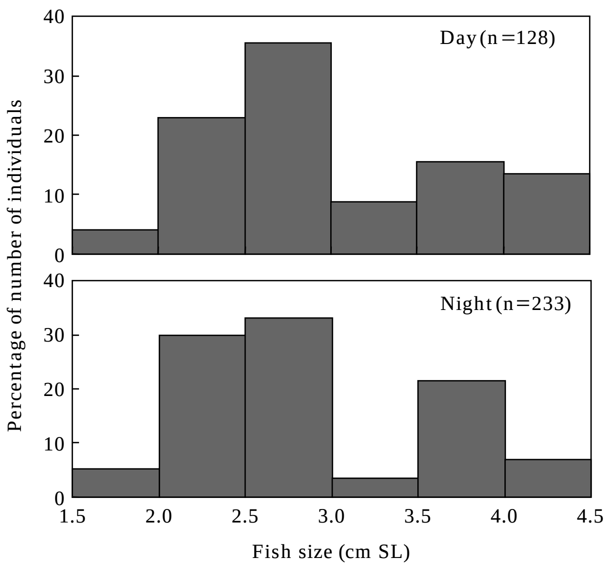

Fig. 2. Size distribution of *Rudarius ercodes* collected during day and night in an eelgrass bed of Jindong Bay.

Table 1. Percent composition of the stomach contents of *Rudarius ercodes* collected during day and night by frequency of occurrence, number and dry weight

Prey organisms	Day Occurrence (%)	Day Number (%)	Day Dry weight (%)	Night Occurrence (%)	Night Number (%)	Night Dry weight (%)
Crustacea	**83.2**	**87.4**	**40.0**	**71.8**	**73.5**	**37.0**
Amphipoda						
Gammaridea	**69.7**	**57.6**	**31.3**	**71.9**	**62.8**	**34.4**
Ericthonius pugnax	36.9	16.7	9.6	35.1	15.8	8.6
Ampelisca sp.	30.1	16.1	8.1	33.3	14.6	8.1
Corophium sp.	23.9	13.9	7.1	25.9	12.8	7.1
Ampithoe sp.	22.1	10.9	6.5	22.6	10.6	4.5
Elasmopus sp.				20.1	5.7	3.4
Melita sp.				18.7	3.3	2.7
Caprellidea	**8.8**	**8.9**	**0.3**	**11.1**	**2.2**	**0.4**
Caprella kroeyeri	3.2	6.1	0.2	6.1	1.5	0.3
Caprella sp.	1.7	2.8	0.1	2.9	0.7	0.1
Copepoda	**14.9**	**20.7**	**8.3**	**23.7**	**7.7**	**0.8**
Calanus sinicus	11.1	9.7	4.1	15.8	7.7	0.8
Centropages sp.	9.2	8.4	3.4			
Tortanus forcipatus	7.6	2.6	0.8			
Tanaidacea						
Tanais cavolinii				3.7	0.5	0.1
Isopoda						
Cymodoce japonica	1.7	0.2	0.1	2.7	0.3	1.3
Polychaeta	**34.9**	**7.5**	**1.5**	**41.8**	**12.1**	**26.7**
Platynereis sp.	17.6	3.1	1.1	21.2	3.4	8.1
Cirratulus sp.				15.2	3.3	7.9
Lumbrineris sp.	10.8	2.3	0.3	11.9	2.1	3.8
Unidentified	15.4	2.1	0.1	13.1	3.3	6.9
Bivalvia	**19.7**	**3.4**	**7.8**	**15.5**	**4.7**	**9.2**
Urochordata						
Stylea sp.	**9.8**	**1.9**	**2.6**	**29.7**	**10.1**	**20.8**
Seagrass						
Zostera marina	**77.5**		**47.8**	**10.1**		**6.6**
Total		100	100		100	100

diet by weight, 57.6% of the diet by number and 69.7% of the diet by occurrence. *Ericthonius pugnax* and *Ampelisca* sp. were the principal prey items. Copepods were also important prey, and bivalves, urochordates, and polychaetes made up most of the remaining food. In contrast, gammarid amphipods, polychaetes, and urochordates were important prey groups at night. Gammarid amphipods were the most important prey consumed, followed by polychaetes and urochordates. Gammarid amphipods accounted for the largest percentage of the diet by dry weight (34.4%). Polychaetes and urochordates, *Styela* sp., were next important prey, making up 26.7% and 20.8% of the diet by dry weight. *Platynereis* sp. and *Cirratulus* sp. were the principal polychaetes items. Eelgrass were consumed by only 6.6% in the diet by dry weight. Bivalves, isopods, copepods, and caprellid amphipods were of minor importance.

Variations of stomach contents in relation to fish size

The pattern of daytime omnivore followed by nocturnal feeding on mainly crustacean prey occurred for all sizes of fish captured in the present study (Fig. 3). Eelgrass and gammarid amphipods made up more than 70% of daytime diets for all fish sizes, although bivalves and polychaetes were found in larger individuals (> 3.5 cm SL). On the other hand, the major food of all size groups captured at night were gammarid amphipods, polychaetes, and urochordates. Smaller *R. ercodes* (< 2 cm SL) fed mainly on gammarid amphipods. The portion of the diet

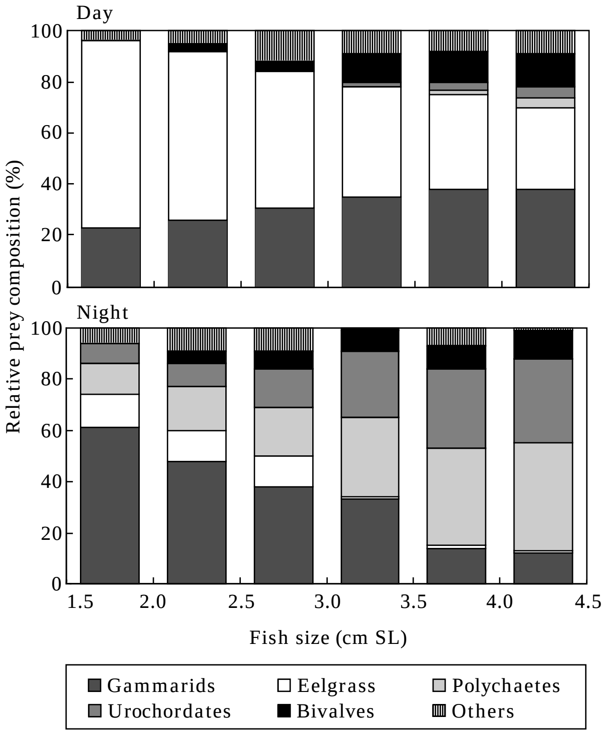

Fig. 3. Relationships between relative prey composition (DW, %) and body length of *Rudarius ercodes* collected during day and night in an eelgrass bed of Jindong Bay.

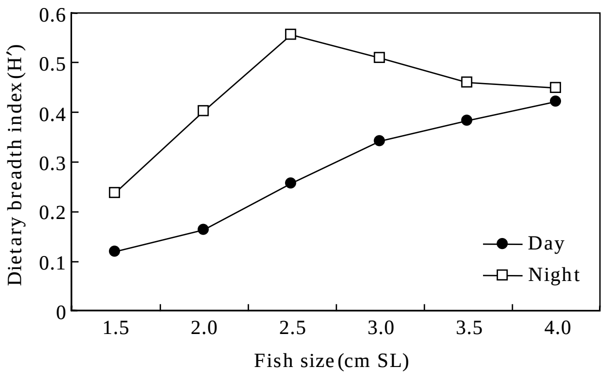

Fig. 4. The size-related variations of dietary breadth index of *Rudarius ercodes* collected during day and night in an eelgrass bed of Jindong Bay.

attributable to gammarid amphipods decreased gradually with increasing size, while proportions of polychaetes, urochordates, and bivalves increased. Eelgrass was only a small portion of the nocturnal diet of most size groups. The marked diel dietary shift from omnivory to mainly carnivore has not previously been reported for *R. ercodes*, or for other monacanthids, although several studies were size-related change of feeding habits of monacanthid fish species in an eelgrass bed, Korea. For example, juvenile *R. ercodes* (<3 cm SL) fed mainly on copepods, whereas the larger individuals fed mainly gammarid amphipods (Kwak and Huh, 2004) and larger individuals of *R. ercodes* (>4 cm SL) consumed mainly on caprellid amphipods and polychaetes in Aburatsubo, central Japan (Horinouchi *et al*., 1998). Likewise, small individuals of *Stephanolepis cirrhifer* (<2 cm SL), one of monacanthid fish species in study area, consumed on copepods, while larger individuals fed on gammarid and caprellid amphipods (Kwak *et al*., 2003). The diel difference in the dietary composition of *R. ercodes* suggest that *R. ercodes* used vision to detect and pursue to prey in the water column during the day, while at night, when visual acuity would be reduced, it employs specialized teeth to bite off heavily small invertebrates and their secretive behavior (Kikuchi, 1974; Conacher *et al*., 1979). The shift towards the above polychaetes and medium-sized crustaceans at night can be attributed to these prey becoming more available for predation, as a result of their nocturnal movement from substrate into the water column (Robertson and Howard, 1978; Robertson and Klumpp, 1983). In addition, high abundances of small crustaceans and polychaetes may probably support diel difference in diet of *R. ercodes* in an eelgrass bed (Horinouchi *et al*., 1998; Pollard, 1984; Kwak, unpublished data). Bell *et al*. (1978) demonstrated that most of monacanthid fish species were presumed to be mid-water feeding fish and have specialized mode of feeding on seagrass and epiphytic organisms with small mouth in the seagrass beds. This may also be true for *R. ercodes* in an eelgrass bed where were observed moving amongst living eelgrass plants near the bottom.

The diel changes in dietary breadth of *R. ercodes* was present with fish size (Fig. 4). Dietary breadth was higher at night than day all size groups. The low dietary breadth of smaller *R. ercodes* increased with increasing fish size during day, whereas high dietary breadth of smaller *R. ercodes* increased to maximum value in 2.5 cm SL, however, this value decreased with larger fish size at night.

The plot of the fullness index during 24-h period showed a peak around 10 : 00 h, 13 : 00 h, and 22 : 00 h on a high tide during spring tide,

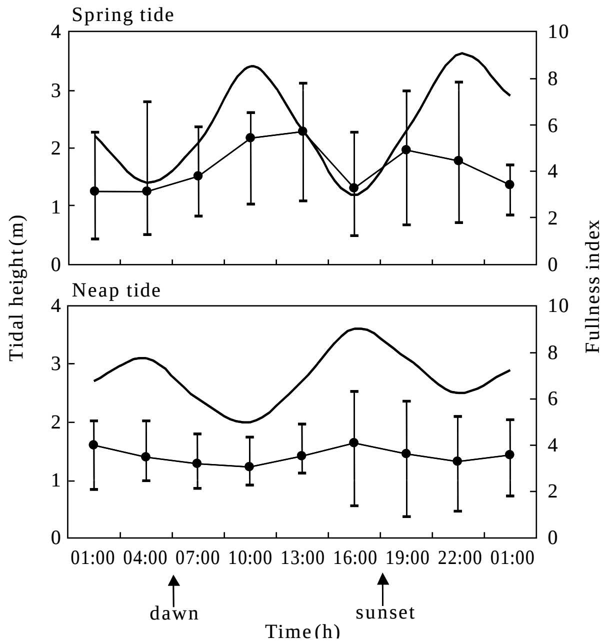

Fig. 5. Fullness index of *Rudarius ercodes* collected during day and night in relation to time and tidal height in an eelgrass bed of Jindong Bay.

and 16 : 00 h on a high tide during neap tide (Fig. 5). Enough water remained over an eelgrass bed for feeding to continue during low tide periods. Robertson and Klumpp (1983) have reported that the feeding strategy of *Hyporhampus melanochir* in the seagrass beds appeared to be an adaptation to diel changes in food availability as well as tidal height. These results suggest that the period of maximum food consumption was during high tides, irrespective of day or night, and spring or neap tides. Rising tides probably make food resources more available to feeding *R. ercodes*. Small invertebrates such as gammarid amphipods and polychaetes rise into the water column on the high tide at night and their number of individuals decrease on low tides (Kwak, unpublished data), thus favouring more intensive feeding during nocturnal rising tides. It is reasonable to assume that eelgrass and small invertebrates (e.g. gammarid amphipods, polychaetes, and urochordates) are equally abundant throughout a 24-cycle.

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그물코쥐치의 먹이습성의 일별 변화: 낮은 잡식성, 밤은 육식성

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진동만 잘피밭에 서식하는 그물코쥐치의 먹이습성의 일별변화를 조사하였다. 출현한 그물코쥐치는 1.6∼4.3 cm SL의 범위였으며, 주요 먹이생물은 단각류에 속하는 옆새우류, 잘피, 갯지렁이류, 그리고 미삭동물이었다. 그물코쥐치의 먹이습성의 일별변화는 뚜렷하였다. 낮에는 잘피와 옆새우류를 주로 먹은 잡식성을, 밤에는 옆새우류, 갯지렁이류, 그리고 미삭동물을 주로 먹는 육식성을 나타내었다. 이와 같은 결과는 낮보다는 밤에 이들 먹이생물의 활동이 활발하여 그물코쥐치가 섭이하기가 용이하였던 것으로 판단된다. 또한 그물코쥐치의 섭이활동은 저조보다는 고조에 활발하였다.