The Journal of the Korean Society of Oceanography
Vol. 30, No. 6, pp. 523-528, December 1995

Diel Horizontal Migration of the Two Mysids *Archaeomysis kokuboi* and *Acanthomysis* sp. in the Sandy Shore Surf Zone of Yongil Bay, Eastern Korea*

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동해 영일만의 모래해변 쇄파대에 사는 곤쟁이류 *Archaeomysis kokuboi*와 *Acanthomysis* sp. 두 종의 주야 수평이동*

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The mysids, *Archaeomysis kokuboi* and *Acanthomysis* sp., clearly exhibited the diel patterns of interspecific horizontal migration in the surf zone at a sandy shore in Yongil Bay, eastern Korea. Shoreward migration of *Acanthomysis* sp. at sunset resulted in the presence of significantly high numbers of mysids after dark at the bottom of 1 m depth. At first light, *Acanthomysis* sp. moved back to deeper water of >1 m depth in conjunction with a reverse migration by *A. kokuboi*. In the afternoon, *A. kokuboi* moved to offshore, then these species remained there. Although *A. kokuboi* has been considered an intertidal species in the exposed beaches with strong wave action, this is not the case in a sandy beach of Yongil Bay. We suggest that evidence for behavioral adaptation comes from the response of *A. kokuboi* to the sheltered beaches with weak wave action. The habitat shifts presumably provide this species with high availability of food materials in the surf zone.

동해 영일만의 모래해안 쇄파대에 사는 곤쟁이류 *Archaeomysis kokuboi*와 *Acanthomysis* sp.는 서로 다른 모습으로 주야 수평이동을 했다. *Acanthomysis* sp.는 어두워지면서 수심 1 m의 저층에서 유의하게 많이 잡혔고 해가 뜨면서 수심 1 m보다 깊은 곳으로 이동했다. 이때 생긴 빈 자리를 *A. kokuboi*가 차지했다. 한편 *A. kokuboi*도 오후가 되면서 수심 1 m보다 깊은 곳으로 이동했다. 파도가 강한 노출형 모래해안에서 *A. kokuboi*는 조간대에 사는 곤쟁이류로 알려졌으나, 영일만 모래해안에서는 조간대에 살지 않았다. 이 현상을 파도가 약한 차폐형 모래해안에 *A. kokuboi*가 적응한 결과로 해석했다. 쇄파대의 풍부한 먹이환경도 서식지를 바꾸는 데 기여한 듯 하다.

INTRODUCTION

The surf zone of sandy shore is an extremely dynamic environment where sand, water and air are always in motion. Sand-burrowing mysids living on sandy beaches occupy a wide range of distance from tropical to subarctic waters (see Mauchline, 1980) and are often predominant (Wooldridge, 1981, 1983; Takahashi and Kawaguchi, 1995). Due to their abundance the beach mysids are thought to play a significant role in the surf-zone food webs (McLachlan, 1983).

*이 논문은 194년도 교육부 학술연구조성비(해양 · 수산과학분야)에 의하여 연구되었음.

A number of workers have addressed the question of migration of sand-burrowing mysids living in beaches with strong wave action (Moran, 1972; McLachlan *et al.*, 1979; Wooldridge, 1981; Webb *et al.*, 1988). However, details of the horizontal migration of beach mysids on a sheltered beach are seldom studied. Moreover, spatial and temporal variation in population density of mysids has traditionally been investigated over time scales of months, where analysis of seasonal events has been objective (Clutter, 1967; Williams and Collins, 1984; Mees *et al.*, 1993). However, we lack an understanding of very short term periodicities that are more closely approximated to the adaptive significance of migration (Macquart-Moulin, 1977; Wooldridge, 1981, 1983; Webb and Wooldridge, 1990; Macquart-Moulin and Maycas, 1995).

Archaeomysis kokuboi Ii, 1964, belonging to the subfamily Gastrosaccinae, is known to be a sand-burrower. This intertidal species occurs abundantly along the east and south coasts of Korea (Ma, 1988) and along Japanese sandy beaches ranged from 37°N to 43°N (Takahashi and Kawaguchi, 1995). The genus *Acanthomysis*, belonging to the subfamily Mysinae, also consists of sand-burrowers (Clutter, 1967). In Korean waters, *Acanthomysis* sp. is morphologically distinct from the other known species (S.-G. Jo, unpublished data). Together with *A. kokuboi*, *Acanthomysis* sp. contributes substantially to surf-zone zooplankton biomass in Yongil Bay (Suh *et al.*, 1995).

This study investigates the nature of the diel horizontal migration of two mysids living in the surf zone and attempts to explain changes in distribution in terms of adaptation to sheltered beaches where little wave action occurred.

MATERIALS AND METHODS

A single station in the surf zone at a sandy beach in Yongil Bay, eastern Korea (Fig. 1), was sampled for benthopelagic mysids from 16:00 h (local time) on 13 August to 14:00 h on 14 August 1993. Beach slope is 1:40 and medium particle diameter is ca 125 μm. Diurnal tide occurred with tidal range of 15 cm;

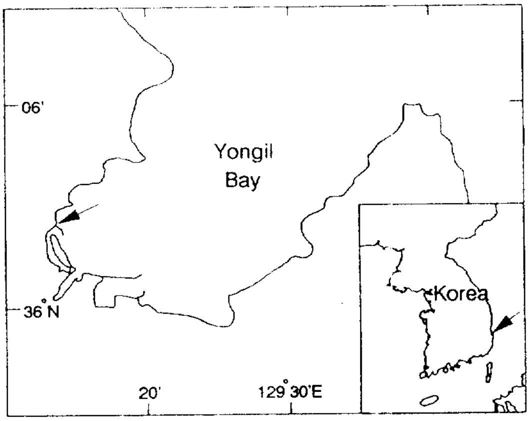

Fig. 1. Location of sampling site at a sandy beach in Yongil Bay, eastern Korea.

low and high waters were 19:30 and 01:31 h with tide height of 29 and 44 cm above mean sea level, respectively (OHA, 1993). The weather was fine and the sea was calm: there is no distinct swash on the shore. Water temperature and salinity at the surface were 21.5°C and 25.9 ppt, respectively.

A sledge net (30 cm width, 12 cm height) was used to collect mysids in the field. The bottom leading edge of this sledge was equipped with a tickler chain of 1 cm width. The sledge was drawn across the substrate on two lateral skids and the upper ca 1 cm of sand agitated and skimmed off by the chain. Mysids and sand particles were swept into a 300 μm-mesh plankton net fixed behind the sledge. We observed good performance of this sledge net in the field using SCUBA diving.

A 22-h study was carried out to investigate a possible change in diel distribution. For this purpose mysids were sampled every 2 h at the three sites in the surf zone; the water's edge and at the surface and bottom of 1 m water depth, ca 40 m offshore. All samples were collected over a distance of 20 m parallel to the shoreline at a speed of ca 1 m s^{-1}. Three replicates were taken at each site on each occasion (*i.e.*, 9 samples × 12 time periods = 108 total samples). The water's edge and bottom samples were taken by skimming the sediment surface, and the surface samples were taken with the net immediately below the water surface. After towing,

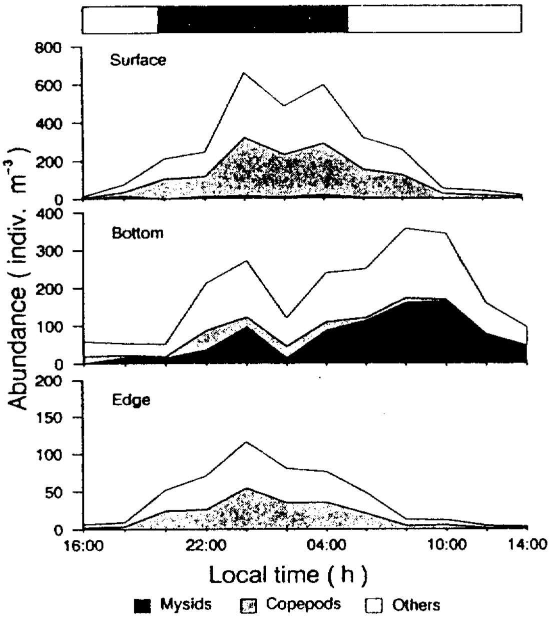

Fig. 2. Diel variation in abundance of zooplankton, copepods and mysids taken at the bottom and surface of 1 m depth and water's edge. The bar along the top indicates night (solid bar) and day (open bars).

the net was washed down with seawater and the cod end contents transferred to glass bottles. Then samples were preserved in 5% buffered formalin seawater.

Mysids were sorted to species and counted under a dissecting microscope. From the net opening dimension of 30×12 cm and towing distance of 20 m, we calculated the total volume of seawater filtered by the net during each sampling as 0.72 m^3 and the total area towed as 6 m^2. Then, collected numbers were converted to the number of individuals per cubic meter of seawater.

The one-way analysis of variance (ANOVA) and multiple comparison were used to test differences in abundance of mysids between time periods; night (20:00 to 04:00 h), morning (06:00 to 12:00 h) and afternoon (14:00 to 18:00 h). The quantitative data were $\log_{10}$ transformed to support the assumptions of ANOVA.

RESULTS

The use of the same sampling method for both

Table 1. Mean abundances (indiv · m^{-3}) of the two mysids for three local time periods at the bottom layers of 1 m depth: night (20:00 to 04 00 h), morning (06:00 to 12:00 h) and afternoon (14:00 to 18:00 h). Underlined values are significantly different from the other time periods (one-way ANOVA and multiple comparison test).

Species	Night	Morning	Afternoon	Level of significance
Archaeomysis kokuboi	15.4	<u>100.8</u>	20.2	P<0.01
Acanthomysis sp.	35.1	26.2	<u>1.7</u>	P<0.05

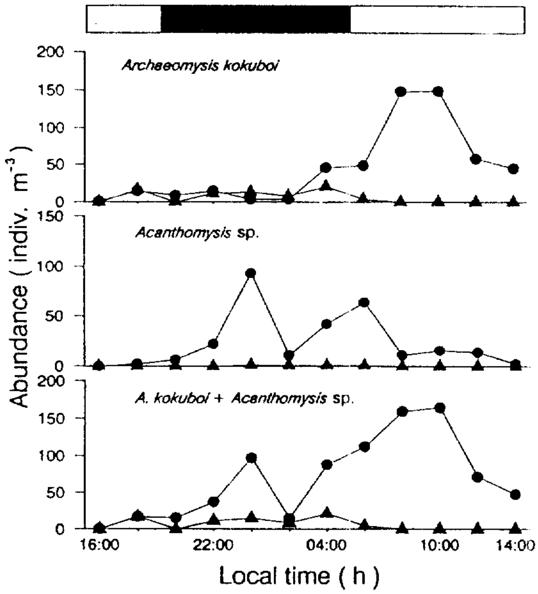

Fig. 3. Mean abundance of two species of mysids taken at the bottom (solid circles) and surface (solid triangles) of 1 m depth every 2 h over the 22 h sampling regime. The bar along the top indicates night (solid bar) and day (open bars).

bottom and surface layers allows us to compare directly the abundance of mysid assemblages in the surf zone (Fig. 2). Two species of mysids, *Archaeomysis kokuboi* and *Acanthomysis* sp., were identified over the 22 h and the former was twice as abundant as the latter. No mysids were taken at the water's edge. In the bottom samples, mean abundance of *A. kokuboi* varied between 148.7 and 0.9 indiv. · m^{-3}, while that of *Acanthomysis* sp. varied between undetectable and 93.6 indiv. · m^{-3}. The peak numbers recorded in the surface samples for *A. kokuboi* and *Acanthomysis* sp. as 20.4 and 1.4 indiv. $\cdot$ m^{-3}, respectively. Significantly greater densities of mysids were found at the bottom than those at the surface (Table 1), suggesting that these species are almost entirely restricted to inhabit near the bottom. Abundances of these mysid species over the 22 h period at the surface and bottom of 1 m water depth were plotted in Fig. 3.

There were significant diel differences in abundance between *Archaeomysis kokuboi* and *Acanthomysis* sp. at the bottom (Table 1); *A. kokuboi* abundance was significantly higher during the daylight the following morning (100.8 indiv. $\cdot$ m^{-3}) and the afternoon (20.2) than in the night (15.4), whereas abundance of *Acanthomysis* sp. was significantly higher during the night (35.1 indiv. $\cdot$ m^{-3}) than in the morning (26.2) or the afternoon (1.7). Additionally, bottom samples of both species are best compared by transforming the abundance of organisms into percentage (Fig. 4). The proportion of *Acanthomysis* sp. to *A. kokuboi* was increased during the night, with the peak of 92% taken at 24:00 h.

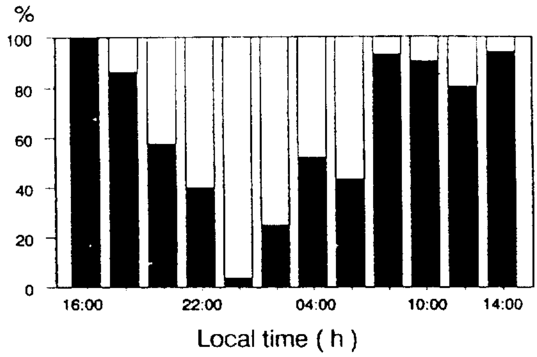

Fig. 4. Composition of two mysids *Archaeomysis kokuboi* (solid bars) and *Acanthomysis* sp. (open bars) taken at the bottom of 1 m depth every 2 h over the 22 h sampling regime.

DISCUSSION

There are two likely patterns of migration in the beach mysids. Firstly, during the day mysids are found burrowing in the top centimeter of sand in and below the swash zone, and then mysids emerge from in the sand and move into deeper water in the evening. Secondly, mysids swim actively when a wave covers the sand, but burrow into the sand immediately when the wave retreats. The first pattern of migration has been proposed for the mysids, all of which belong to the genus *Gastrosaccus; G. sanctus* (Moran, 1972), *G. simulans* (Nath and Pillai, 1973) *G. mediterraneus, G. spinifer* (Macquart-Moulin, 1977) and *G. psammodytes* (McLachlan *et al.*, 1979, Wooldridge, 1981). The second pattern, on the other hand, has been reported in two species of the genus *Archaeomysis*, such as *A. vulgaris* (Jo and Hanamura, 1993) and *A. kokuboi* (Takahashi and Kawaguchi, 1995).

In this study, the two species of mysids showed significant differences in diel horizontal migration (Table 1). During the morning, *A. kokuboi* was present at the bottom of 1 m water depth. After noon, they migrated to deeper water of >1 m depth and remained there till the morning. On the other hand, during the day *Acanthomysis* sp. was absent at the bottom of 1 m depth. After dark, this species moves onshore from deeper waters of >1 m depth. At first light, *Acanthomysis* sp. migrated back offshore. The results have clearly indicated that distribution of *A. kokuboi* was separated from that of *Acanthomysis* sp., although there was a short overlapping time at dawn (Fig. 3). This phenomenon seems to be mainly caused by diel differences of a migratory behavior between two species (Fig. 4).

Since there was evidence that *A. kokuboi* occupies a narrow range of horizontal distance from swash zone to the area of ca 2 m water depth (Ma, 1988; Takahashi and Kawaguchi, 1995), we *a priori* expected to be a lot of mysids in the water's edge of a sandy beach in Yongil Bay. This was certainly not the case in this study: there was no mysids in the water's edge. We suggest that this absence of *A. kokuboi* in the water's edge was caused by change of beach conditions or wave actions, which are the major factors making the swash. It is likely that *A. kokuboi* changes their habitat to the area of ≥ 1 m depth. The sandy beach we studied is classified as the sheltered beach, according to criteria for assessing the degree of exposure of sandy beaches by Brown and McLachlan (1990). In the sheltered beach, calmer sea conditions prevent development of swash zone on the sandy shore. Thus behavior changes may give mysids great advantages of feeding under conditions when swash does not prevail.

There is general agreement that mysids are not only omnivorous, consuming detritus and small living organisms, but also feeding by filtration and predatory (Mauchline, 1980; Wooldridge and Webb, 1988). Clutter (1967) suggested that the circulation of a large amount of detrital food material around the breaker zone could be the major factor influencing the distribution of nearshore mysids. Webb and Wooldridge (1990) also reported that diel horizontal migration of the mysid *Mesopodopsis slabberi* was closely related with increased concentration of phytoplankton. Accumulation of organic matter on the shallower part of the sandy beach is a potentially rich source of food to mysids. Calmer sea conditions during summer may promote this accumulation. Then high availability of food allows mysids to remain shallow part of beach.

^{210}Po concentration in biogenic substances may provide an approach for understanding its food source and trophic level in a marine ecosystem (Heyraud and Cherry, 1979; Cherry *et al.* , 1987). According to Suh *et al.* (1995), the mean values of ^{210}Po concentration factors of zooplankton collected from Yongil Bay were 2.4×10^5 in *Calanus sinicus* (herbivorous Copepoda), 4.1×10^5 in *Paracalanus indicus* (herbivorous Copepoda), 23.5×10^5 in *Labidocera bipinnata* (carnivorous Copepoda), 6.6×10^5 in *Archaeomysis kokuboi* (Mysidacea) and 4.9×10^5 in *Acanthomysis* sp. (Mysidacea). The values of mysids were higher than those of herbivorous copepods, but lower than that of carnivorous copepod. These results support that mysids of the surf zone at a sandy beach in Yongil Bay are omnivorous, eating mainly detritus. In addition, *A. kokuboi* had a higher value than *Acanthomysis* sp., suggesting the former occupies slightly higher trophic levels than the latter.

ACKNOWLEDGEMENTS

We are grateful to Ho Young Soh, Young-Kyung Koo and Ok-Hwan Yu for their assistance during the sampling, and two reviewers for their comments on the manuscript. This study was supported in part by the Korea Inter-University Institute of Ocean Science Program, Ministry of Education, 1994.

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Accepted September 14, 1995