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Resting Eggs of Copepods in the Intertidal Sediments of Gomso Bay, the West Coast of Korea

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To investigate the distribution of resting eggs at the intertidal zone, Gomso Bay, samples were taken from the top of the sediments to 10 cm depth at four sites using a cylindrical corer in February, 1997. Additional samples were also taken from one station at subtidal zone to compare the distributions between the inter- and subtidal zones. The resting eggs of four copepods, *Acartia pacifica, Centropages abdominalis*, *Calanopia thompsoni*, and *Tortanus forcipatus* were studied. Mostly, the abundance of the resting eggs in the lower intertidal zone was greater than that in the upper intertidal zone, but was not significantly different from that in the subtidal zone. The abundance of the resting eggs in the intertidal sediments was related with the grain-size and moisture content of sediments. Intertidal sediments are potential egg banks like subtidal sediments.

Key words: Resting eggs, Intertidal sediments, Copepods, Zooplankton, Gomso Bay

INTRODUCTION

Although most copepods in seawater are holoplankton, some are meroplankton and produce resting eggs, prior to their disappearance from water column during unfavourable season (Madhupratap *et al.*, 1996). The spawned resting eggs sink to the sea-bottom and stay in the sediments as dormant until favorable conditions such as temperature and oxygen concentration resume (Pandian, 1994). In temperate waters, resting eggs are usually produced to survive low temperature prevailing during winter; likewise, the eggs in tropical waters are produced to withstand the high summer temperature (Grice and Marcus, 1981; Madhupratap *et al.*, 1996).

Recruitment of planktonic copepods producing resting eggs may greatly be affected by hatching of the resting eggs (Naess, 1991; Marcus, 1984). Reappearance of newly hatched planktonic copepods from the benthic resting eggs a few months after disappearance from the water column affects the population dynamics of plankton community.

Survival and hatching of the resting eggs in sediments may depend on water depths. In shallow coastal waters, the resting eggs in the sediments have high potential to hatch and to return to the sea surface as plankton while those in deep waters have few opportunities except upwelling areas. In shallow waters, higher number of resting eggs in the sediments exposed to disturbance would hatch in the water column than those in the undisturbed sediments. Therefore, sediments of the intertidal zone with high chance of disturbance would play a important role as benthic egg bank. Previous studies on the distribution of copepod resting eggs have been from subtidal waters except George and Lindley (1997) who reported the egg abundance from the intertidal sediments. However, George and Lindley (1997) focused on hatching of nauplii from aerobic and anaerobic sediments rather than on the distribution and abundance from the intertidal sediments.

The west coast of Korea has intertidal areas as wide as 10 km in maximum, whose slope is very gentle (Je and Choi, 1998). Resting eggs of copepods may be abundant in the intertidal sediments, if so, which should be a significant benthic egg reservoir for copepod communities. The present study explores the distribution of resting eggs of calanoid copepods in the intertidal sediments in Gomso Bay, the west coast of Korea. In addition, the distribution patterns of the eggs between the intertidal and subtidal sediments are compared.

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MATERIALS AND METHODS

Study area and collection of sediments

Samples were collected from the bottom sediments of Gomso Bay, which is 20 km long, 7–9 km wide, and characterized by long tidal channels and broad intertidal zone. The tidal zone occupies most of the bay, accounting up to 75 km^2 (Chang *et al.*, 1996). The tide of the bay is semi-diurnal, and has the mean and maximum tidal differences of 4.34 m (5.90 m at spring tide and 2.78 m at neap tide) and 7.07 m, respectively (Chang, 1995). Station 1 was located in subtidal zone (3 m deep at low tide), Stations 2–4 were situated between the subtidal zone and the mean sea level (hereafter, referred to as MSL), and Station 5 above MSL. Triplicate samples were taken from four intertidal stations (Fig. 1) with a hand-made corer (6 cm×50 cm length) at low tides in February 1997. On the other hand, the subtidal sediment samples were carefully collected from a 3 m depth by a SCUBA diver with minimum disturbance. The samples were transported to a laboratory within 2 hours and stored in the darkness at 3°C.

Profile of study site and analysis of sediments

The slopes of the study site were measured by observing the location of deflection points on a line vertical to coastal line with a Total Station (TC 2002, Leica). Collected sediments were sieved using wet sieving method (63 μm) after adding H_2O_2 (80%) to remove organic matter in the sediment. Sands were sieved with a roetap sieve shaker (for 15 minutes) to measure the percentage composition by 0.5 ϕ size. Percentage of sediment moisture content was determined by measuring weights of sediments before and after drying wet sediments in an oven at 110°C for two hours: that is, sediment moisture content (%) =100×(wet weight-dry weight)/wet weight.

Isolation and identification of eggs

Three days after the sediment collection, the upper 10 cm of the sediments were divided at 2 cm intervals. After shaken and sonicated for 30 seconds (Branson 8210), each sample was filtered through a 55-μm Nitex-mesh screen. To isolate the eggs, the material retained on the sieve was carefully transferred into sugar solution (1:1 of table sugar and distilled water) (Onbé, 1978) to be centrifuged at 3000 rpm for 3 minutes (Vision VS-5500). The supernatant was washed in a 55 μm sieve with filtered seawater onto a petri dish. The eggs were sorted by the shape and size under a microscope (Zeiss Stemi SV6; Nikon Optiphot-2). For identification of the eggs, Kasahara *et al.* (1974), Marcus (1990), Viitasalo and Katajisto (1994), and Madhupratap *et al.* (1996) were referred.

RESULTS

Sediment textures

In the study site, several creeks shallower than 1.5 m deep were present (Fig. 1). Silt dominated the sediments (Fig. 2); its mean grain size became gradually coarse from the higher tidal level toward the lower tidal level. As stations became closer to low tidal level, the portion of silt usually decreased, while that of sand or clay increased. Sediment moisture increased toward low tidal level.

Egg morphology

The size, colour, and surface of the eggs were: 93.2±13.1 (mean±standard deviation), brown and spinous for *Acartia pacifica,* 75.5±3.4 μm, light green

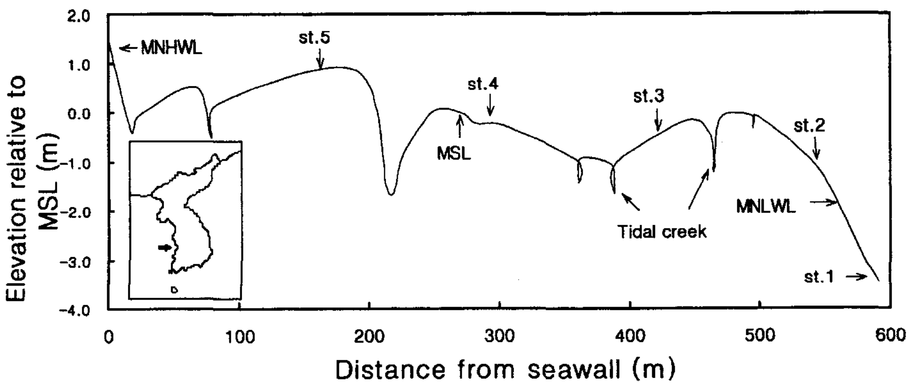

Fig. 1. Map and profile of the sampling stations in Gomso Bay, western Korea. MNHWEL=mean neap high water level; MNLWL =mean neap low water level.

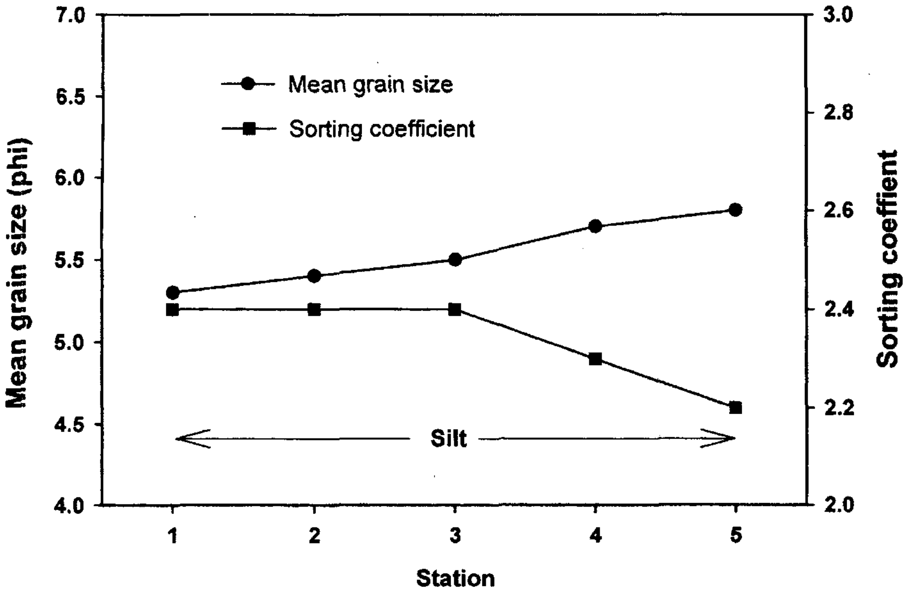

Fig. 2. Type of top 10 cm sediments at each sampling station.

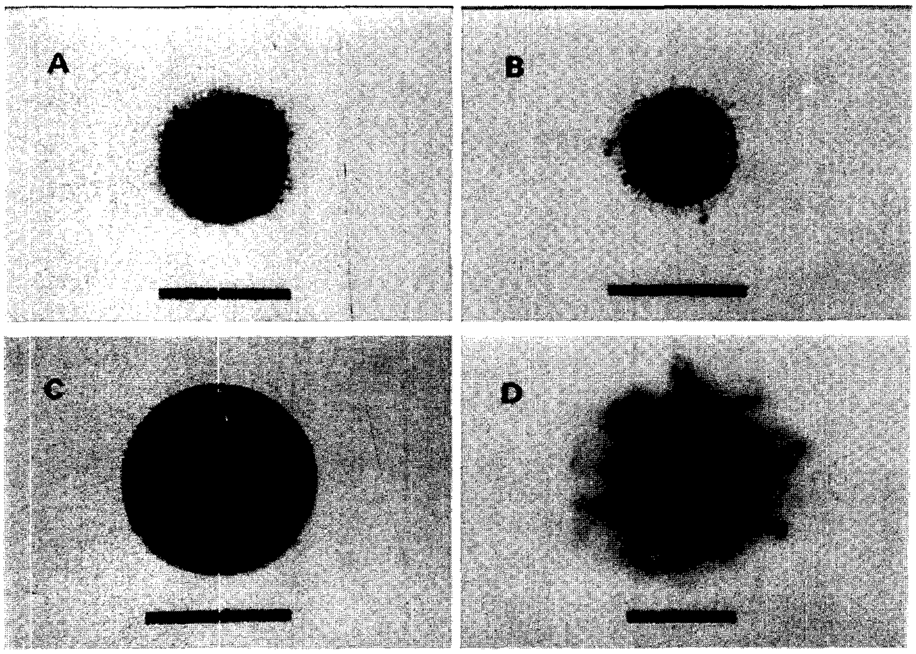

Fig. 3. Resting eggs of copepods identified. A, *Acartia pacifica*; B, *Centropages abdominalis*, C, *Calanopia thompsoni*; D, *Tortanus forcipatus*. Scale bars indicate 100 μm.

and spinous for *Centropages abdominalis*, 106.4± 16.6 μm, light green with a case for *Tortanus forcipatus*, and 133.5±19.0 μm, green with smooth surface for *Calanopia thompsoni* (Fig. 3).

Egg abundance and horizontal distribution

The abundance of the resting eggs in the top 10 cm sediments varied greatly with species and station (Fig. 4). It ranged from 0 to 6.0×10^4 eggs/m^2 for *A. pacifica*, 0 to 5.2×10^4 eggs/m^2 for *C. abdominalis*, 0 to 5.1×10^4 eggs/m^2 for *C. thompsoni* and 0 to 1.5×10^4 eggs/m^2 for *T. forcipatus*.

The horizontal distribution pattern of the eggs also varied with species (Fig. 4). The abundance of the resting eggs was highest at Station 2 for *A. pacifica*, *C. abdominalis*, and *C. thompsoni*, while no eggs were found at the upper two stations (Fig. 4). Although the highest density was observed for 3 species at Station 2, there was no significant difference between Station 2 and subtidal station (St. 1) except for *C. thompsoni*. The abundance of *T. forcipatus* eggs was relatively low and they occurred at Stations 2 and 3, only.

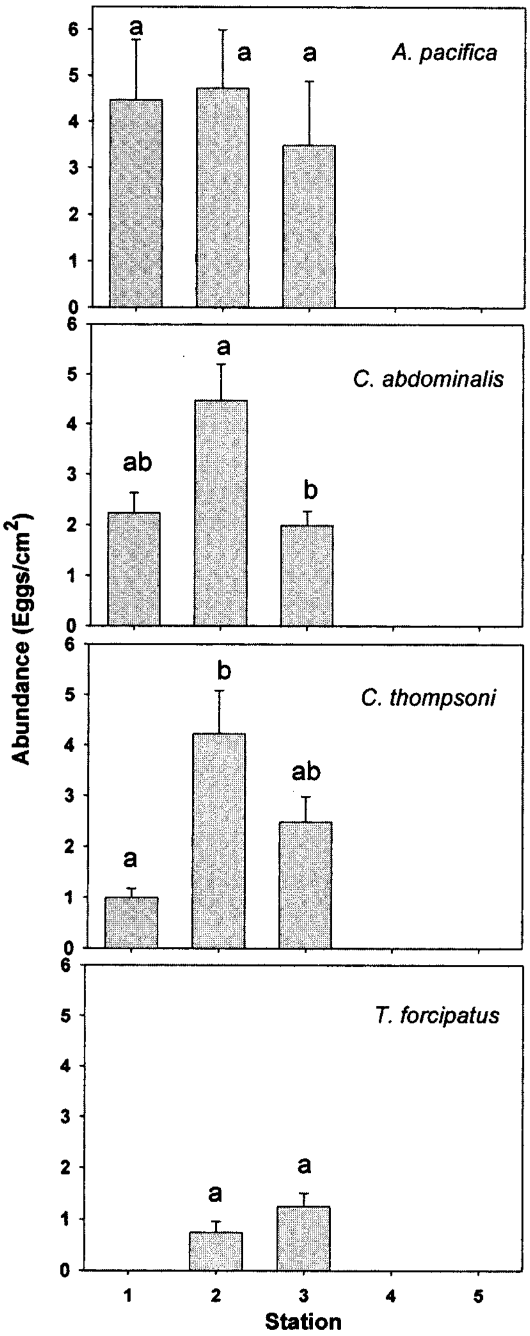

Fig. 4. Abundance (+sd) of resting egg of four copepods in the top 10 cm sediments at different stations in February. Abundance of each species sharing a common letter is not significantly different (p>0.05).

Vertical distribution

The vertical distribution of the resting eggs in the top 10 cm sediments varied with species and sampling stations. More than half the total eggs were present in the top 4 cm sediment at Stations 1 and 2 for *A. pacifica* (Fig. 5), 4–6 cm depth at Station 1 for *C. abdominalis* (Fig. 5), top 8 cm depth for *C. thompsoni* (Fig. 6) and top 6 cm depth for *T. forcipatus*. Especially for *A. pacifica*, the sediment depth where the density of eggs was highest increased as approaching toward the land. Most eggs (89.2–100%) of all 4 species were found in the top 8 cm depth.

Grain size and moisture content

The distribution of resting eggs of copepods is related with the grain size of the sediments; the abundance of the resting eggs was highest in the sediments of the grain size between 5.4 ϕ and 5.5 ϕ (Fig. 7). The abundance of resting eggs in the intertidal sediments was also related with the moisture content of the sediment. With decreasing moisture content of the sediment, the abundance of the eggs decreased and below the 20% level no eggs were found at the upper intertidal sediments above or near MSL (Fig. 7).

DISCUSSION

In this study, only four copepod species were identified and studied. The resting eggs of 13 copepod species from the Asian waters including Japan coastal waters through the year have been reported (Madhupratap *et al.*, 1996). It may result from the difference in sampling sizes. If more samples would be taken from the sediments in this study area, other copepod resting eggs should have been present in the sea-bottom sediments of Gomso Bay. A future study may have to cover this aspect.

Although there have been many studies on the distribution of copepod resting eggs in the subtidal waters (Madhupratap *et al.*, 1996; Marcus, 1989, 1990, 1995; Naess, 1991; Viitasalo and Katajisto, 1994), a few studies have been made in the intertidal bottom sediments. George and Lindley (1997) was the first to report the resting eggs from intertidal sediments, but their study was mainly focused on the hatching of eggs exposed to different conditions. Therefore, the present study was designed to deal with the abundance of the eggs in the intertidal sediments and to compare the abundance in the intertidal sediments with that in the subtidal sediments, which may indicate the relative importance of intertidal sediments as an egg reservoir. This study has shown that the highest egg density occurred at the lower part of intertidal sediments (below MSL), with no significant differences between the lower intertidal sediments and subtidal sediments. On the other hand, there was

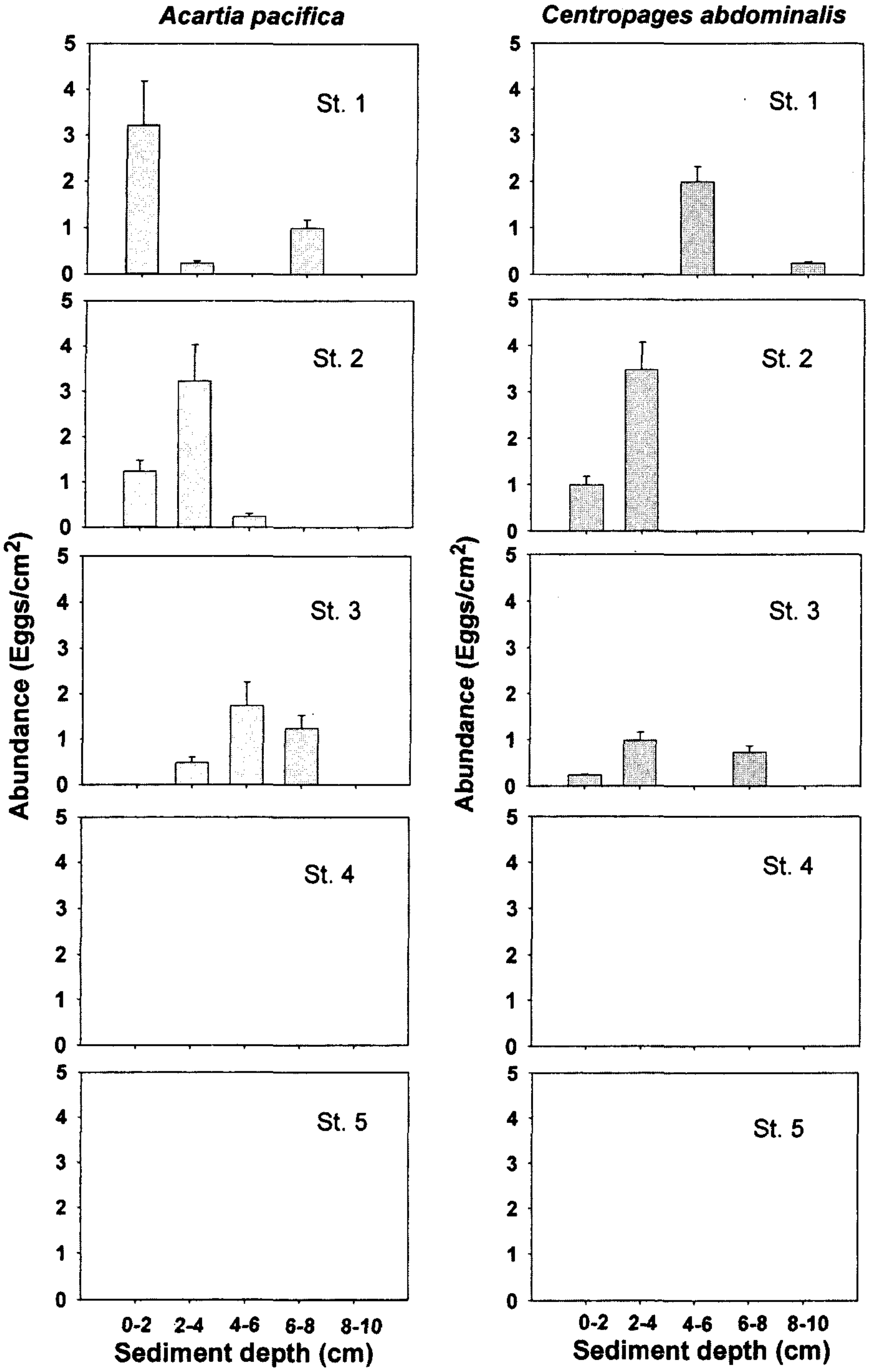

Fig. 5. Vertical distribution of *Acartia pacifica* and *Centropages abdominalis* resting eggs in the top 10 cm sediments at different stations in February. (St. 1, subtidal; Sts. 2–5, intertidal).

usually no egg in the upper part of intertidal sediments (above and near MSL). The intertidal areas of the western Korea vary from about 1 km up to 10 km in width. Consequently, the intertidal sediments below MSL in western Korea may be a significant egg reservoir for copepod plankton community. Yet, the highest density of the resting eggs (5.2×10^4 egg/m^2) recorded in the present study is for *Centropages abdominalis* and is lower than that (1.5×10^6 egg/m^2) reported for *C. yamadai* from the Inland Sea, Japan by Kasahara *et al.* (1975).

The distribution of resting eggs in the sediments might be affected by physical, biological, and chemical factors such as winds, waves, tidal currents, toxic materials, anoxic condition, and bioturbation (Marcus, 1986; Marcus and Lutz, 1998). In this study, the

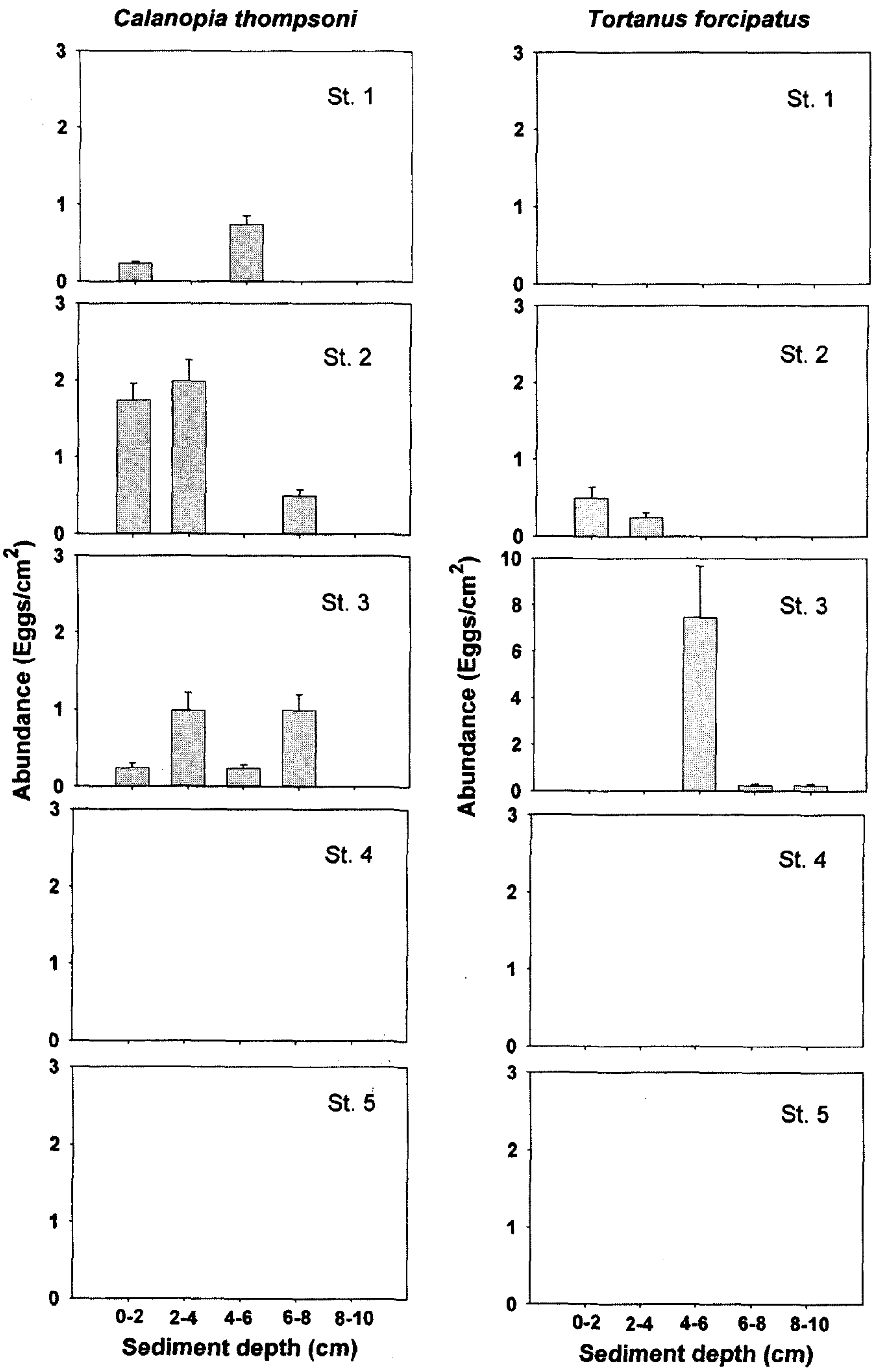

Fig. 6. Vertical distribution of *Calanopia thompsoni* and *Tortanus forcipatus* resting eggs in the top 10 cm sediments at different stations in February. (St. 1, subtidal; Sts. 2–5, intertidal).

abundances of copepod resting eggs were usually higher in the top 8 cm of sediments. The egg density below the top 8 cm depth is low probably due to exposure to anoxia or H_2S for a long time (Marcus *et al.*, 1994).

The present study has also shown that the presence of the eggs was related with moisture content of the sediment. Absence of the eggs at the upper intertidal sediments may partly be due to the fact that they are usually so small and spherical (<150 in diameter) that the ratio of surface area to volume is high, leading to greater desiccation, even though they are somewhat tolerant of adverse conditions such as temperature. In that sense, the moisture in the intertidal

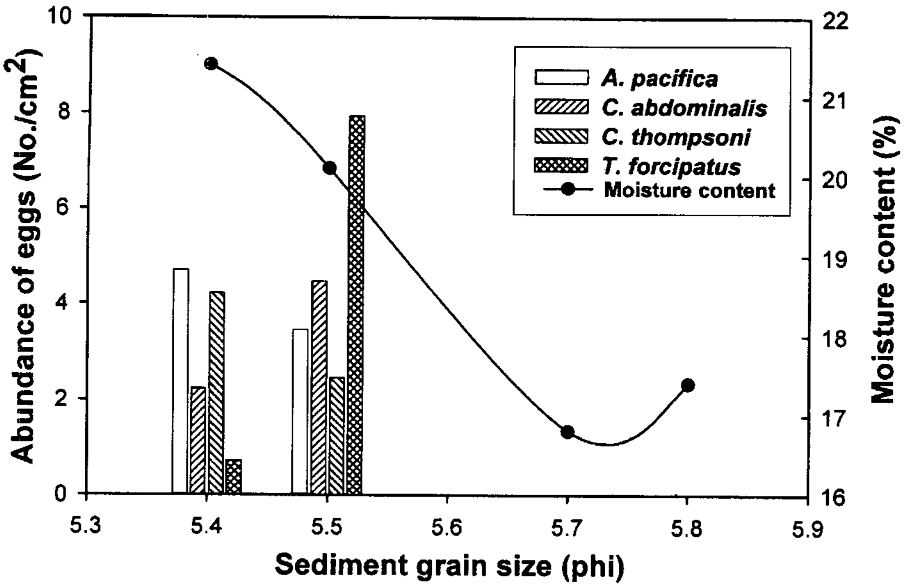

Fig. 7. The relationship between the abundance of copepod resting eggs and the moisture content of the sediment, and the sediment grain size.

sediments might affect the survival of the eggs (Fig. 7). In *A. pacifica*, for example, the depth where the density of eggs was highest tended to be deeper from the subtidal station toward the land.

My observation that the abundance of the resting eggs is dependent on grain size of the sediment (Fig. 7) confirms the earlier reports. For instance, Marcus and Taulbee (1992) reported that the distribution of eggs of *Acartia tonsa* and *Labidocera aestiva* in the sea bottom following a resuspension event should be highly dependent upon the grain size composition of the sediment.

For further understanding the population dynamics of zooplankton, in particular, hatch rate of the eggs in the intertidal zone (species specific) will be necessary to assess the role of sediments.

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REFERENCES

Chang, J.H., 1995. Depositional processes in the Gomso Bay tidal flat, west coast of Korea. Ph. D. thesis, Seoul Nat'l Univ., 192pp (in Korean).

Chang, J.H., Y.A. Park and S.-J. Han, 1996. Late quaternary stratigraphy and sea-level change in the tidal flat of Gomso Bay, west coast of Korea. The Sea. *J. Korean Soc. Oceanogr.*, **1(2)**: 59–72 (in Korean).

George C.L. and J.A. Lindley, 1997. Hatching nauplii of planktonic calanoid copepods from intertidal estuarine sediments. *J. Mar. Biol. Ass. U.K.*, **77**: 899–902.

Grice, G.D. and N.H. Marcus, 1981. Dormant eggs of marine copepods. *Oceanogr. Mar. Biol. Ann. Rev.*, **19**: 125–140.

Je, J.G. and J.W. Choi, 1998. Intertidal flat in a crisis. In: Marine Pollution and the Environment of the Earth., edited by Kang, S.H., KORDI, Ansan, pp. 50–55 (in Korean).

Kasahara, S., S. Uye and T. Onbé, 1974. Calanoid copepod eggs in sea-bottom muds. *Mar. Biol.*, **26**: 167–171.

Kasahara, S., S. Uye and T. Onbé, 1975. Seasonal cycles of abundance in the populations of several species of copepods and their eggs in the Inland Sea of Japan. *Mar. Biol.*, **31**: 16–25.

Madhupratap, M., S. Nehring and J. Lenz, 1996. Resting eggs of zooplankton (Copepoda and Cladocera) from the Kiel Bay and adjacent waters (southwestern Baltic). *Mar. Biol.*, **125**: 77–87.

Marcus, N.H., 1984. Recruitment of copepod nauplii into the plankton: importance of diapause eggs and benthic processes. *Mar. Ecol. Prog. Ser.*, **15**: 47–54.

Marcus, N.H., 1986. Recruitment of individuals into the plankton: the importance of bioturbation. *Limnol. Oceanogr.*, **31(1)**: 206–210.

Marcus, N.H., 1989. Abundance in bottom sediments and hatching requirements of eggs of *Centropages hamatus* (Copepoda: Calanoida) from the Alligator harbor region, Florida. *Biol. Bull. Mar. Biol. Lab., Woods Hole*, 176: 142–146.

Marcus, N.H., 1990. Calanoid copepod, cladoceran, and rotifer eggs in sea-bottom sediments of northern Californian coastal waters: identification, occurrence and hatching. *Mar. Biol.*, **105**: 413–418.

Marcus, N.H., 1995. Seasonal study of planktonic copepods and their benthic resting eggs in northern California coastal waters. *Mar. Biol.*, **123**: 459–465.

Marcus, N.H. and R.V. Lutz, 1998. Longevity of subitaneous and diapause eggs of *Centropages hamatus* (Copepoda: Calanoida) from the northern Gulf of Mexico. *Mar. Biol.*, **131**: 249–257.

Marcus, N.H., R. Lutz, W. Burnett and P. Cable, 1994. Age, viability, and vertical distribution of zooplankton resting eggs from an anoxic basin: evidence of an egg bank. *Limnol. Oceanogr.*, **39(1)**: 154–158.

Marcus, N.H. and K. Taulbee, 1992. Potential effects of a resuspension event on the vertical distribution of copepod eggs in the sea bed: a laboratory simulation. *Mar. Biol.*, **114**: 249–251.

Naess, T., 1991. Marine calanoid resting eggs in Norway: abundance and distribution of two copepod species in the sediment of an enclosed marine basin. *Mar. Biol.*, **110**: 261–266.

Onbé, T., 1978. The life cycle of marine cladocerans. *Bull. Plankton Soc. Japan*, **25(1)**: 41–54 (in Japanese with English abstract).

Pandian, T.J., 1994. Arthropoda-Crustacea. In: Reproductive Biology of Invertebrates, Vol. 6. B, edited by Adiyodi, K.G. and R.G. Adiyodi, Oxford and IBH Publishing, New Delhi, pp. 39–166.

Viitasalo, M. and T. Katajisto, 1994. Mesozooplankton resting eggs in the Baltic Sea: identification and vertical distribution in laminated and mixed sediments. *Mar. Biol.*, **120**: 455–465.

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