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<Note>

Salinity Effects on the Survival of the Metazooplankton in the Coastal Waters off the Seamankeum Areas

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A huge freshwater reservoir (ca. 12,000 ha) will be created when the construction of a 33-km dike on a huge mud flat of the Saemankeum areas is established. A large quantity of freshwater will emerge to the adjacent sea from the reservoir through two big gates. Marine organisms outside the dike are expected to frequently experience low salinity waters. To investigate the salinity effects on the dominant metazooplankton in the coastal waters off Saemankeum areas, we measured the survival (Survival 1H and Survival 24H) of 11 different taxa (the copepods *Acartia omorii*, *A. pacifica*, *Calanus sinicus*, *Centropages abdominalis*, *Paracalanus indicus*, *Pseudodiaptomus inopinus*, *Tortanus forcipatus*, and a hydromedusa, and barnacle nauplius, polychaeta larva, and a chaetognath *Sagitta* sp.) at salinities of 0, 5, 10, 15, 20, 25, 30, 35, and 40 psu when the organisms were exposed for 1 and 24 h, respectively. Survival 1Hs of *P. inopinus* and barnacle nauplius were 100% between 5 and 35 psu, while they were 0% at salinities of 0 and 40 psu. Survival 1Hs of *A. omorii* and *A. pacifica*, *P. indicus*, *T. forcipatus*, and polychaeta larva were 100% at salinities $\geq$ 10 psu, while they were 0% at lower salinities. Survival 1Hs of a hydromedusa and *Sagitta* sp. were 100% at salinities $\geq$ 15 psu, while they were 0% at lower salinities. Survival 1H of *C. abdominalis* and *C. sinicus* was 100% at salinities $\geq$ 20 psu, while they were 0% at lower salinities. Survival 24Hs of *A. omorii*, *A. pacifica*, *C. abdominalis*, barnacle nauplius, and polychaeta larva were the same as Survival 1Hs at the same salinity, while those of the other metazooplankton were lower than Survival 1Hs. The results of the present study suggest that low salinity water emerging from big gates may cause the death of the metazooplankton, but the salinities at which death of the metazooplankton occurs may differ by species.

Key words: Barnacle, Chaetognath, Copepod, Hydromedusa, Polychaeta

INTRODUCTION

The Saemankeum Project is a national project in which the Korean government is converting a huge mud flat (ca. 40,000 ha) of the Saemankeum area, Jeon Buk, Korea, into a vast rice field and a freshwater reservoir by constructing a 33-km long and 280-m wide dike among Byeonsan Bight, Go-Gunsan Island chains, and Gunsan. A semi-closed artificial bay outside the dike (the Byeonsan Bight Saemankeum dike Go-Gunsan Island chains) will appear when the dike is constructed. A huge freshwater reservoir will newly arise when the dike on a huge mud flat is established. A large quantity of freshwater will emerge from the reservoir (ca. 12,000 ha) through two big gates. Marine organisms outside the dike are expected to frequently experience low salinity waters.

Marine metazooplankton species play a very important role in food webs as major consumers of phytoplankton (Frost, 1972; Fernandez, 1979; Teegarden *et al*, 2001; Jeong *et al.*, 2001; Stoecker *et al.*, 2002) and heterotrophic protists (Gifford and Dagg, 1988; Jeong, 1994, 1999; Stoecker and Egloff, 1987; Stoecker and Sanders, 1985) and as an important food source for diverse carnivores (particularly the juveniles of most commercially important fish) (Koslow, 1981). Owing to their numerical importance and linkages, changes in their abundances can significantly affect the abundances of other marine organisms making up ecosystems (Mullin & Conversi, 1988; Jeong, 1994). If they are

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killed due to lowered salinity caused by large freshwater drainage, the structure and function of the marine ecosystem off Saemankeum may become considerably altered. In other waters salinity has been reported to markedly affect the distribution of metazooplankton (Collins & Williams, 1981; Park *et al.*, 2002).

To better understand salinity effects on the metazooplankton outside the Saemankeum dike, we conducted experiments to measure the survival of the metazooplankton collected from the coastal waters off Saemankeum areas.

MATERIALS AND METHODS

The adult copepods *Acartia omorii*, *A. pacifica*, *Calanus sinicus*, *Centropages abdominalis*, *Paracalanus indicus*, *Pseudodiaptomus inopinus*, *Tortanus forcipatus*, and a hydromedusa, barnacle nauplius, polychaeta larva, and a chaetognath *Sagitta* sp., dominant metazooplankton taxa in the coastal waters off Saemankeum areas, were collected from the coastal waters off Saemankeum areas, Kunsan, and the Keum River Estuary using a 45-cm mouth, 303-µm mesh net in April, October, and November, 2003 (Table 1). These organisms were maintained in 20-L polyethylene bottles in a culture room for 1-2 h before experiments. The temperature at the culture room was maintained identical to the water temperature when the organisms were collected.

Forty-psu seawater was established by evaporation in a clean room and lower salinity waters (0, 5, 10, 15, 20, 25, 30, 35, and 40 psu) were produced by mixing 40 psu water with distilled water. Water of each salinity was distributed into each well of a 6-well plate chamber (ca. 18 ml in volume of a well). Triplicate wells for each salinity were set up. Five actively swimming individuals of each taxon were transferred into each well containing 10-ml target-salinity water by using a micropipette. The 6-well plate chambers were placed on the shelf in the culture room as described above. After 1 and 24 h incubation, the living and dead individuals were enumerated.

For all organisms, Survival 1H and Survival 24H was calculated as the percentage (%) of surviving individuals relative to the total number of individuals examined after exposure to target salinity for 1 and 24 h, respectively.

RESULTS

Survival after 1 h exposure

Survival 1Hs of all metazooplankton species (*Acartia omorii*, *A. pacifica*, *Calanus sinicus*, *Centropages abdominalis*, *Paracalanus indicus*, *Pseudodiaptomus inopinus Tortanus forcipatus* and a hydromedusa, barnacle nauplius, polychaeta larva, and *Sagitta* sp.) tested in the present study were 100% at salinities of 20–35 psu, while they were different at the other salinities (Fig. 1A); Survival 1Hs of *P. inopinus*, and barnacle

Table 1. Metazooplankton taxa used in the present study. Length (L, mm) and width (W, mm) are the mean values of 5 individuals for each metazooplankton taxon. Sampling date, locations, water temperature, and salinity at collection site all given. Keum River Estuary (KRE), Kunsan Outer Port (KOP), and Saemankeum (SMK). SD=Standard deviation.

Species	L (±SD)	W (±SD)	Date (2003)	Location	T (°C)	S (psu)
Copepoda						
Acartia omorii	0.8(±0.06)	0.2(±0.03)	April 21	KRE	16.0	21.3
Acartia pacifica	1.3(±0.14)	0.3(±0.04)	Oct. 30	SMK	13.9	29.9
Calanus sinicus	3.6(±0.25)	0.9(±0.10)	Oct. 30	SMK	13.9	29.9
Cnetropages abdominalis	1.6(±0.14)	0.4(±0.03)	Oct. 30	KOP	13.3	29.1
Paracalanus indicus	0.8(±0.05)	0.2(±0.02)	Oct. 30	KOP	13.3	29.1
Pseudodiaptomus inopinus	1.3(±0.10)	0.4(±0.03)	Nov. 2	KRE	14.3	5.2
Tortanus forcipatus	1.7(±0.10)	0.5(±0.05)	Nov. 2	SMK	13.6	30.3
Larvae						
Barncale nauplius	1.3(±0.11)	0.5(±0.07)	Oct. 30	KRE	14.8	18.9
Polychaeta larvae	2.2(±0.12)	0.3(±0.05)	April 21	KRE	16.0	21.3
Others						
Sagitta sp.	4.2(±0.17)	0.4(±0.03)	April 21	KRE	16.0	21.3
Hydromedusae	1.9(±0.34)	1.9 (±0.34)	April 21	KRE	16.0	21.3

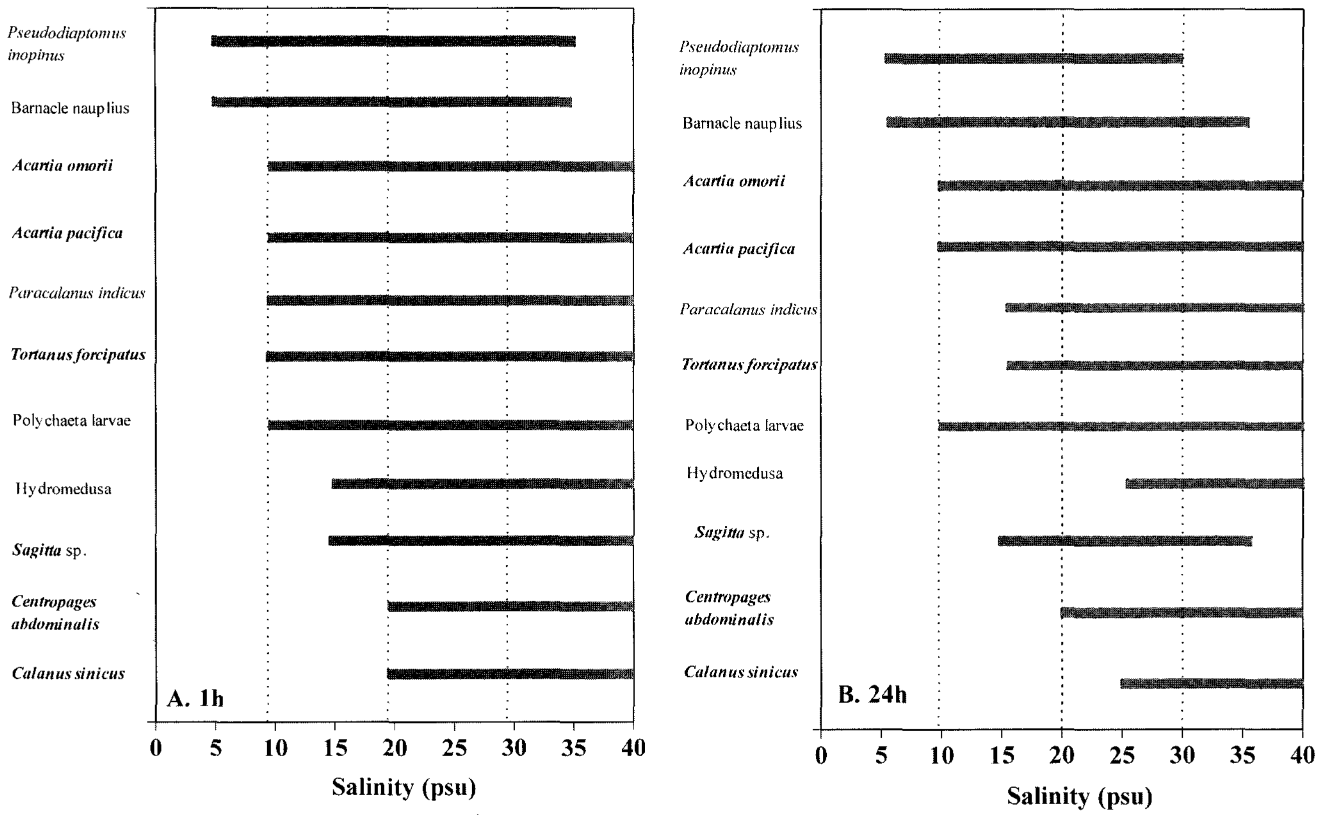

Fig. 1. Salinity ranges where each metazooplankton taxon tested in the present study survived after 1 h (A) and 24 h (B) exposure.

nauplius were 100% between 5 and 35 psu, while they were 0% at lower or higher salinities. Survival 1Hs of *A. omorii*, *A. pacifica*, *P. indicus*, *T. forcipatus*, and polychaeta larva were 100% at salinities ≥ 10 psu, while they were 0% at lower salinities. Survival 1Hs of a hydromedusa and *Sagitta* sp. were 100% at salinities ≥ 15 psu, while they were 0% at lower salinities. Survival 1Hs of *C. abdominalis* and *C. sinicus* were 100% at salinities ≥ 20 psu, while they were 0% at lower salinities.

Survival after 24 h exposure

Survival 24Hs of *A. omorii*, *C. abdominalis*, *A. pacifica*, barnacle nauplius, and polychaeta larva were the same as Survival 1Hs at the same salinity, while those of the other metazooplankton were lower than Survival 1Hs; Survival 24Hs of *P. inopinus* were 100% between 5 and 30 psu, while they were 0% at lower or higher salinities (Fig. 1B). Survival 24Hs of *P. indicus* and *T. forcipatus* were 100% at salinities ≥ 15 psu, while they were 0% at lower salinities. Survival 24Hs of a hydromedusa and *C. sinicus* were 100% at salinities ≥ 25 psu, while they were 0% at lower salinities. Survival 24H of *Sagitta* sp. was 100% at salinities of 15–35 psu, while they were 0% at lower or higher salinities.

DISCUSSION

The present study shows that the survival of marine metazooplankton living in the coastal waters off Saemankeum areas were markedly affected by salinity, but different species had different tolerances; the low salinity tolerance of tested marine organisms at a given salinity decreased in the following sequence: for the Survival 1H, *Pseudodiaptomus inopinus*-barnacle nauplius > *Acartia omorii*-*A. pacifica*-*Paracalanus indicus*-*Tortanus forcipatus*-polychaeta larva > hydromedusa-*Sagitta* sp. > *Centropages abdominalis*-*Calanus sinicus* (Fig. 1A); for the Survival 24H, *P. inopinus*-barnacle nauplius > *A. omorii*-*A. pacifica*-polychaeta larva > *P. indicus*-*T. forcipatus*-*Sagitta* sp. > *C. abdominalis* > hydromedusa-*C. sinicus* (Fig. 1B).

The copepods tested in the present study have a wide range of salinity tolerance. According to our field data, salinity ranges in which some copepods were present in the coastal waters off Saemankeum and Kunsan and the Keum River Estuary were similar to these salinity laboratory data where the copepods

Table 2. Salinity range in which each metazooplankton taxon had been observed in the coastal waters off Saemankeum, Kunsan, and Keum River Estuary between 1999 and 2002.

Species	Salinity range (psu)
Copepoda	
Acartia omorii	5.1–31.3
Acartia pacifica	28.9–32.1
Calanus sinicus	23.0–32.1
Centropages abdominalis	25.2–31.9
Paracalanus indicus	10.4–32.1
Pseudodiaptomus inopinus	3.7–12.8
Tortanus forcipatus	23.0–32.1
Larvae	
Barnacle nauplius	3.7–32.1
Polychaeta larvae	3.7–32.1
Others	
Sagitta sp.	10.4–32.1
Hydromedusae	25.5–32.1

survived (Table 2); *Pseudodiaptomus inopinus,* which survived at salinities between 5 and 35 psu after 1 h exposure, was present at salinities between 4–13 psu. However, this species has been reported to be present at salinities between 1 and 29 psu in the Mankyeong-Dongjin River Estuary (the present study area; Suh *et al.*, 1991) and Seomjin River Estuary (Kim *et al.* 2000). *Acartia omorii,* which survived at salinities between 10 and 40 psu after 1-h exposure, was present at salinities between 5–31 psu. *Paracalanus indicus,* which survived at salinities between 10 and 40 psu, after 1-h exposure was present at salinities between 10 and 32 psu. *Centropages abdominalis,* which survived at salinities between 20 and 40 psu after 1-h exposure, was present at salinities between 25 and 32 psu. *Calanus sinicus,* which survived at salinities between 20 and 40 psu after 1-h exposure, was present at salinities between 22 and 33 psu. This species has been reported to be present at salinities between 9 and 33 psu in the Seomjin River Estuary (Park *et al.* 2002) and between 18 and 32 psu in the Mankyeong-Dongjin River Estuary and Kwangyang Bay (Soh & Suh, 1993; Choi *et al.*, 1998; Suh *et al.*, 1991). *A. pacifica* and *Tortanus forcipatus* could survive at salinities as low as 5–10 psu, but they were found at salinities of 23–32 psu. Unknown factors besides salinity might affect the distribution of these two copepods. The results of the present study suggest that the species composition of these copepods may be affected by lower salinity waters produced due to freshwater discharge from the freshwater reservoir.

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REFERENCES

Choi, S.D., Y.S. Kim and K.H. Han, 1998. The characteristic of zooplankton community in Kwangyang Bay, Korea. *Bull. Yosu Nat'l Univ.* **13**(2): 959–971 (in Korean).

Collins, N.R. and R. Williams, 1981. Zooplankton of the Bristol channel and severn estuary. The distribution of four copepod in relation to salinity. *Mar. Biol.* **64**(3): 273–283.

Fernandez, F. 1979. Nutritional studies in the nauplius larva *of Calanus pacificus* (Copepoda: Calanoida). *Mar. Biol.*, **53**: 131–147.

Frost, B.W., 1972. Effects of size and concentration of food particles on the feeding behavior of the marine planktonic copepod *Calanus pacificus*. *Limnol. Oceanogr.*, **17**: 805–815.

Gifford, D.J. and M.J. Dagg, 1988. Feeding of the estuarine copepod *Acartia tonsa* Dana: carnivory vs. herbivory in natural microplankton assemblages. *Bull. Mar. Sci.*, **43**: 458–468.

Jeong, H.J., 1994. Predation effects by the calanoid copepod *Acartia tonsa* on the heterotrophic dinoflagellate *Protoperidinium* cf. *divergens* in the presence of co-occurring red-tide dinoflagellate prey. *Mar. Ecol. Prog. Ser.*, **111**: 87–97.

Jeong, H.J., H.J. Kang, J.H. Shim, J.K. Park, J.S. Kim, J.Y. Song and H.J. Choi, 2001. The interactions among a toxic dinoflagellate *Amphidinium carterae*, the heterotrophic dinoflagellate *Oxyrrhis marina*, and the calanoid copepods *Acartia* spp. *Mar. Ecol. Prog. Ser.*, **218**: 77–86

Jeong, H.J., 1999. The ecological roles of heterotrophic dinoflagellates in marine planktonic community. *J. Euk. Microbiol.*, **46**: 390–3[illegible].

Kim, K.S., J.B. Lee, K.W. Lee, J.W. Kang and H.B. Yoo, 2000. Ecology study of copepoda community in the lower Seomjin river system, Korea, *Kor. J. Lim.* **33**: 176–186 (in Korean).

Koslow, J.A., 1981. Feeding selectivity of schools of northern Anchovy, *Engraulis mordax*, in the southern California Bight. *Fish. Bull.*, **79**: 131–142.

Mullin, M.M. and A. Conversi, 1988. Biomass of euphausiids and smaller zooplankton in the California current - Geographic and interannual comparisons relative to the Pacific Whiting, *Merluccius productus*, fishery. *Fish. Bull.*, **87**: 633–644.

Park, C., P.G. Lee and S.R. Yang, 2002. Variation of zooplankton distribution in the Seomjin river estuary with respect to season and salinity [illegible] dients. *J. Kor. Soc. Ocean.* **7**(2): 51–59 (in Korean).

Soh, H.Y. and H.L. Suh, 1993. Seasonal fluctuation of the abundance of planktonic copepods in Kwangyang bay. *Koran. J. Environ. Biol.* **11**(1): 26–34 (in Korean).

Stoecker, D.K. and D.A. Egloff, 1987. Predation by *Acartia tonsa* Dana on planktonic ciliates and rotifers. *J. Exp. Mar. Biol. Ecol.*, **110**: 53–68.

Stoecker, D.K. and N.K. Sanders, 1985. Differential grazing by *Acartia tonsa* on a dinoflagellate and a tintinnid. *J. Plankton Res.*, **7**: 85–100.

Stoecker, D.K., M.W. Parrow, J.M. Burkholder and H.B. Glasgow, 2002. Grazing by microzooplankton on *Pfiesteria piscicida* cultures with different histories of toxicity. *Aquat. Microb.*

Ecol., **28**: 79–85.

Suh, H.L., H.Y. Soh and S.S. Cha, 1991. Salinity and distribution of zooplankton in the estuarine system of Mankyong river and Dongjin river. *J. Oceanol. Soc. Korea*, **26**(3): 181–192 (in Korean).

Teegarden, G.J., R.G. Campbell and E.G. Durbin, 2001. Zooplankton feeding behavior and particle selection in natural plankton assemblages containing toxic *Alexandrium* spp. *Mar. Ecol. Prog. Ser.*, **218**: 213–226.

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