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A Review on the Copepods in the South Sea of Korea

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Ecological and taxonomical studies on the copepods were reviewed in order to make data bases on the species composition, abundance, distributional pattern, and seasonal variations of copepods in the South Sea of Korea. Total 179 species have been reported in this area. The dominant species in the coastal waters and embayments, such as *Acartia clausi, Paracalanus parvus, Oithona similis,* and *Oithona nana,* were different from those reported in the offshore waters around Cheju Island. Indicator species of the South Sea were also discussed in this paper. Copepod abundances were higher in the coastal waters, up to more than 390,000 individuals/m^3(collected with a 150 μm mesh net), than in the offshore waters. There were two types of temporal variations in copepod abundances in the coastal waters, i.e., bimodal abundance peaks in spring and fall, and unimodal peak during summer to early fall.

Introduction

Copepods are the most important metazoan zooplankton in coastal waters because of their numerical dominance and trophic importance. They were reported as a dominant group in the coastal waters around Korea(Park, 1956; Lee, 1972; Park, 1973; Park *et al.,* 1973; Shim and Ro, 1982; Shim and Park, 1982; Ro, 1982; Shim and Lee, 1983; Kim, 1984; Kwak, 1990; Yoo, 1991). They play an important role in the marine food web, serving as a primary food source for many small carnivores and as grazers on phytoplankton.

Studies on the species composition, abundance, and distributional pattern of copepods in the coastal waters around Korea have been actively conducted, and lots of data have been accumulated in the Yellow Sea(Ro, 1982; Shim and Park, 1982; Cho *et al.,* 1983; Kim and Huh, 1983; Shim and Lee, 1983; Huh *et al.,* 1987; Kim, 1987; Sim *et al.,* 1988; Park, 1989; Kwak, 1990; Shim and Yoon, 1990; Park *et al.,* 1991; Shin, 1991; Suh *et al.,* 1991; Yoo, 1991; Park *et al.,* 1992), in the South Sea(Lee, 1972; Park and Lee, 1982; Shim and Ro, 1982; Kim, 1984; KORDI, 1981, 1982, 1987, 1988, and 1989; Kang, 1988; Lee, 1989; Park *et al.,* 1990), and in the East Sea (Hue, 1967; Shim and Lee, 1986, Kang, 1989; Choi, 1991; Park et al., 1991). As seen in the numbers of references above, the information on the copepods in the South Sea is relatively limited compared with that of the Yellow Sea.

The South Sea of Korea is shallow, with the depth of less than 200*m*. The surface temperature is over 30℃ during the summer season, and warmer (around 10℃) than the Yellow Sea and the East Sea during the winter season due to the effect of the Tsushima Current(KORDI,1989), which is a branch of the Kuroshio Current. The South Sea is an economically important area for fisheries and aquaculture. Therefore, it would be valuable to review the information on the copepods which are principal food sources for fishes.

The purposes of this study were to make a list of the copepod species reported in the previous studies in the South Sea of Korea, and to describe spatial and temporal variations in abundances and distributional pattern of copepods in order to supply data bases for future studies in this area.

Materials and Methods

This review study was performed based on the previous studies about taxonomy and ecology of copepods in the South Sea. The South Sea was defined as the waters around the southern part of the Korean Peninsula, i.e., the western boundary is the line between Chindo and Chagwido, the southern boundary is between Udo and Osesaki in Japan, and the eastern boundary is between Ulgi and Kawajirimizaki in Japan(Fish. Res. Dev. Agency, 1979; see Fig. 1). Copepods were classified into three groups such as calanoid copepods, cyclopoid copepods, and harpacticoid copepods, and the species previously reported in the South Sea are listed in Table 1 with the references. Table 1 also shows the seasons when copepods occurred and locations where they were collected.

Results and Discussion

Species composition

Total 179 species of copepods have been reported in the South Sea. More species were reported in the South Sea than in the Yellow Sea, where 148 species were identified(Yoo, 1991). The dominant species were *Oithona similis, Paracalanus parvus,* and *Calanus helgolandicus* in the Korea Strait(Park, 1956), *Oithona nana, P. parvus, Acartia clausi,* and *Temora turbinata* in Jinhae Bay(KORDI, 1982), *O. similis, P. parvus, Corycaeus affinis, C. helgolandicus,* and *Centropages abdominalis* in Jinhae Bay(=Chinhae Bay) and adjacent waters(Lee, 1982), *P. parvus, O. nana, O. similis, C. affinis,* and *Tortanus forcipatus* in the embayments near Yeosu(=Yosu) (Shim and Ro, 1982), *P. parvus, O. similis, A. clausi,* and *C. affinis* in Kwangyang Bay(Kim, 1984), *Acartia pacifica, Calanus sinicus, Oncaea media,* and *Oncaea venusta* around Cheju Island(KORDI, 1989), *Oithona davisae, O. similis,* and *P. parvus* in Masan Bay(Lee, 1989), and *A. clausi* and *C. abdominalis* in the southern coastal waters(Park *et al.*, 1990). In general, dominant species in the coastal waters and embayments of the South Sea, as described above, were different from those in the offshore waters(see Kang, 1992 for the oceanic calanoid copepods).

Most of the dominant species reported in the South Sea were also found in the Yellow Sea(see Table 1 in Yoo, 1991). Some species, such as *Eurytemora pacifica, Paracalanus crassirostris, Pontella latifurca* and *Tortanus spinicaudatus,* were reported as the characteristic species in the Yellow Sea(Yoo, 1991). However, *E. pacifica* and *P. crassirostris* were also reported in the South Sea(Kim, 1985; Lee, 1989).

Some of the dominant species, such as *Acartia clausi, Paracalanus parvus,* and *Calanus helgolandicus* had been in taxonomical argument. For example, *A. clausi,* one of the dominant species reported in the South Sea of Korea, was renamed as *Acartia omorii* by Bradford(1976) in Tokyo Bay, and Ueda (1986) distinguished *A. clausi* into two species such as *A. omorii* and *Acartia hudsonica* from Japanese waters. Since then, taxonomical studies on the copepods belonging to the genus *Acartia* have been actively conducted in the Korean waters(Kang and Lee, 1990; Yoo *et al.*, 1991). Kang and Lee(1990) reported the morphological differences between *A. omorii* and *A. hudsonica,* and Yoo(1991) reported that *A. omorii* was a dominant species in the Yellow Sea. This species was also found in the South Sea (Lee, 1989).

Paracalanus parvus, reported as a dominant species in the Yellow Sea(Shim *et al.*, 1988), was not in the zooplankton list in another study(Yoo, 1991) conducted in the same waters, which reported *Paracalanus indicus* as a dominant species. Therefore, further taxonomical studies on the species belonging to genus *Paracalanus* should be needed. *Calanus helgolandicus* and *Calanus finmarchicus,* which had been reported, were known as *Calanus sinicus* in Sagami Bay, Japan(Kitachi, 1979 cited in Kim, 1985). Lee(1986) compared the characteristics of a copepod, belonging to genus *Calanus,* collected in the southern coastal waters of Korea with those of *C. sinicus, C. finmarchicus, C. helgolandicus* and *Calanus pacificus* reported in the previous studies(references are therein) in detail, and concluded that this species was *C. sinicus.* However, he suggested that further studies would be necessary

Table 1. A list of copepod species previously reported in the South Sea of Korea.

Species	References																Seasons				Locations
																	S	S	F	W	
CALANOIDA																					
Acartia bifilosa					5		7										*			*	MS, YK
A. clausi	1	2	3	4					9	10		12	13	14	15	16	*	*	*	*	S-E, S, KY, PS, YS, K-st, J-C, DR
A. danae					5							12	13		15	16		*	*	*	S-E, JH, K-st, J-C
A. erythraea	1		3		5		7		9	10		12						*	*	*	MS, JH, KY, YS, PS, J-C, S-E, DR
A. hamata												12							*		S-E
A. hudsonica					5		7										*	*	*	*	MS
A. longiremis															15			*			J-C
A. negligens					5				9	10		12						*	*	*	S-E, CJ, DR
A. omorii					5		7										*	*	*	*	MS
A. pacifica							7		9	10		12	13					*	*		S-E, MS, K-st, DR
A. sinjiensis					5		7											*			MS
A. spinicauda	1		3		5		7		9	10		12			15			*	*	*	S-E, MS, KY, DR, YS, J-C
A. steueri					5		7		9								*		*	*	MS, CJ, PS
Acrocalanus gibber									9			12	13		15	16			*		S-E, K-st, J-C
A. gracilis	1										11		13					*	*		YS, S, K-st
A. longicornis									9		11							*	*		S
Calanopia elliptica				4								12			15	16			*		S-E, S, J-C
C. minor											11					16		*	*		S, S-E
C. thompsoni	1								9	10	11					16		*	*		YS, S, S-E, DR
Calanus cristatus												12							*		S-E
C. darwini (=*Cosmocalanus darwini*)											11	12					*	*	*	*	S-E, S
C. finmarchicus												12							*		S-E
C. gracilis (=*Neocalanus gracilis*)									9		11									*	S, CJ
C. helgolandicus	1	2								10		12	13		15	16	*	*	*	*	S-E, PS, YS, DR, K-st, J-C, S
C. minor (=*Nannocalanus minor*)									9		11	12			15	16	*	*	*	*	S-E, S, J-C
C. pauper (=*Canthocalanus pauper*)									9	10	11	12			15	16		*	*		S-E, S, J-C, DR
C. sinicus			3				7		9								*	*	*	*	MS, KY
C. tenuicornis (=*Mesocalanus tenuicornis*)									9		11	12	13		15	16	*	*	*	*	S-E, S, K-st, J-C
C. vulgaris		2															*	*	*	*	PS
Calocalanus pavo									9		11		13		15	16		*	*		S, S-E, J-C
C. plumulosus				4							11		13			16		*	*		S, S-E, TS
Candacia bipinnata									9		11	12					*	*	*	*	S-E, S, PS
C. bradyi											11					16			*		S, S-E
C. catula											11	12	13				*	*	*		S-E, S
C. cruta											11								*		CJ
C. pachydactyla									9		11								*		S, PS
C. truncata									9		11	12						*	*		S-E, S, CJ
Centropages abdominalis	1		3	4			7		9				13		5	6	*	*	*	*	S-W, S-E, MS, S, KY, YS, PS, J-C
C. bradyi											11		13					*	*		S, TS
C. calaninus											11								*		S
C. dorsispinatus									9						15	16		*	*		S, S-E, J-C
C. furcatus			3	4					9			12			15	16		*	*		S-E, S, KY, J-C
C. gracilis											11	12						*	*		S-E, S

Table 1. (Continued)

Species	References	Seasons S	S	F	W	Locations
C. mcmurrichi	10	*			*	DR
C. orsinii	16			*		S-E
C. violaceus	12			*		S-E
C. yamadai (=*C. tenuiremis*)	1 3 9 10 12 15 16	*	*	*	*	S-E, KY, YS, J-C, DR
Clausocalanus arcuicornis	13 16		*	*	*	S-E, J-C
C. furcatus	9 11 15 16	*	*	*	*	S, S-E, J-C
C. pergens	9 10 11 12 16	*	*	*	*	S-E, S, K-st, DR
Ctenocalanus vanus	12 13	*	*	*	*	S-E, K-st, J-C
Euaetideus acutus	9	?				CJ
Eucalanus attenatus	9 11 13	*	*	*	*	S, S-E
E. crassus	9 11 12	*	*	*	*	S-E, S
E. mucronatus	9 11 12 13 16		*	*	*	S-E, S, K-st
E. subcrassus	11 12 13 15 16		*	*	*	S-E, S, CJ
E. subtenuis	9 11	*			*	S
Euchaeta concinna	9 11 12	*		*	*	S-E, S
E. flava	16			*		S-E
E. longicornis	11 12	*		*		S-E, S
E. marina	2 9 12 15 16	*	*	*	*	S-E, PS, S, J-C
E. plana	11 12 15 16	*	*	*	*	S-E, S-W, S, J-C
E. rimana	11	*	*	*	*	S
E. russellii (=*Pareuchaeta russeli*)	9 11	*	*	*	*	S-W, S
E. wolfendeni	11			*		CJ, TS
Eurytemara herdmani	15	*	*	*	*	J-C
E. pacifica	7	*	*		*	MS
Gaidius pungens	12			*		S-E
Gaetanus armiger	12			*		S-E
G. minor	9	?				S
Haloptilus longicornis	9 11				*	CJ, PS
Heterorhabdus papilliger	12			*		S-E
Labidocera acuta	9 12 16		*	*		S-E, PS, CJ
L. bipinnata	1 3 7 9 10 12 15 16		*	*		S-E,MS, KY, YS, J-C, DR
L. detruncata	16		*			S-E
L. euchaeta	1 3 15 16		*	*		KY, YS, J-C, S-E
L. japonica	10 15 16		*	*		J-C, S-E, DR
L. kroyeri	1 3 10 15 16		*	*		KY, YS, J-C, S-E, DR
L. minuta	10 16			*		S-E, DR
L. pavo	9 10		*			KY, DR
Lucicutia clausi	9 11	*	*	*	*	S, CJ
L. flavicornis	9 11 12 13 16	*		*	*	S-E, S-W, S, PS
L. ovalis	11 12			*	*	S-W, S
Mecynocera clausi	15 16			*		J-C, S
Metridia lucens	12 15			*		S-E, J-C
Paracalanus aculeatus	1 9 10 12 13 15 16		*	*		S-E, YS, K-st, J-C, DR
P. crassirostris	9	?				S
P. parvus	1 2 3 7 9 10 12 13 14 15 16	*	*	*	*	S-E,MS,KY,PS,YS,K-st,JH,J-C,DR
Pareuchaeta elongata	13		*			K-st
Pleuromamma abdominalis	11	*		*		S

Table 1. (Continued)

Species	References	Seasons S	S	F	W	Locations
P. borealis	9					PS
P. gracilis	4 9 11 12 13 16	*	*	*	*	S-E, S-W, S, CJ
P. robusta	9 11	*		*	*	S, CJ
Pontella chierchiae	9 16		*			CJ, S-E
P. fera	9 16		*			CJ, PS, S-E
P. longipedata	15				*	J-C
P. plumata	16			*		S-E
P. spnicauda	9					CJ
P. securifer	10			*		DR
P. surrecta	1	?				YS
Pontellopsis tenuicauda	9		*			CJ
P. yamadae	9	?				CJ
Pseudocalanus minutus	12 13 15 16			*		S-E, K-st, J-C
Pseudodiaptomus marinus	1 3 7 9 10 15 16	*	*	*	*	MS, KY, YS, J-C, S-E, DR
Rhincalanus cornatus	9 11	*		*	*	S
R. nasutus	9 11 12 13	*	*	*	*	S-E, S
Scolecithricella bradyi	9	?				CJ
S. dentata		*				S-E
S. longispinosa	9	?				CJ strait
S. minor	12			*		S-E
Scolecithrix danae	9 11 12 13 15	*	*	*	*	S-E, S, J-C
S. nicobarica	7 9 16	*	*		*	MS, S, S-E
Sinocalanus tenellus	9 15		*			NT, J-C
Temora discaudata	1 4 9 12 13 15 16	*	*	*	*	S-E, S, YS, J-C
T. stylifera	9 12 13 15 16		*	*		S-E, K-st, J-C
T. turbinata	1 3 7 9 10 12 14 15 16		*	*	*	S-E, MS, KY, YS, JH, J-C, DR
Temoropia mayumbaensis	16	?				S-E
Tortanus discaudatus	13		*			PS
T. forcipatus	1 3 7 10 12 15 16		*	*	*	S-E, MS, KY, YS, J-C, DR
T. gracilis	10		*			DR
Undinopsis bradyi	12			*		S-E
Undinula darwini (=*Cosmoscalanus darwinii*)	4 9 11 13 15	*	*		*	S-W, S, K-st, J-C
U. vulgalis	1 3 9 11 12 13 15 16		*	*		S-E, KY, YS, S, K-st, J-C
CYCLOPOIDA						
Copilia longistylis	16				*	S-E
C. mirabilis	16			*		S-E
Copolia asiaticus	13	*				S-E
C. quadrata	13		*			S-E
Corycaeus affinis	1 3 6 7 10 13 15 16	*	*	*	*	S, MS, KY, YS, K-st, J-C, S-E, DR
C. agilis	16		*			YS, S-E
C. andrewsi	6 7 15 16		*	*		S, S-E, MS, J-C
C. asiaticus	16			*		S-E
C. catus	6 13 15 16		*	*		S, K-st, J-C, S-E
C. crassiusculus	6 13 16		*		*	S, S-E
C. dahli	1	?				YS
C. dubisu	1	?				YS
C. erythraeus	6		*			S

Table 1. (Continued)

Species	References																Seasons S	S	F	W	Locations
C. gibbulus		2								10					15	16	*	*	*	*	PS, J-C, S-E, DR
C. lautus															15	16			*		J-E, S-E
C. longisty		2															*	*	*	*	PS
C. ovalis																16			*		S-E
C. rostratus																16			*		S-E
C. pacificus						6											*				S
C. speciosus						6	7						13			16		*	*		S, MS, S-E
C. trukicus	1																?				YS
Farranula gibbula						6												*			S
Lubbockia marukawai												12							*		S-E
L. squillimana															15					*	J-C
Oithona atlantica							7	8									*	*	*		CJ, MS
O. attenuata							7	8										*	*		MS
O. brevicornis							7	8									*	*	*		JH, CJ, MS
O. davisae							7	8									*	*	*	*	JH, KY, MS
O. decipiens								8								16		*	*		CJ, S-E
O. fallax								8				12						*	*		S-E, CJ
O. longispina								8									*	*			CJ
O. nana	1							8		10		12	13	14	15	16	*	*	*	*	S-E, JH, CJ, YS, J-C, DR
O. oculata								8										*	*		PS
O. plumifera		2						8				12	13		15	16	*	*	*	*	S-E, CJ, PS, K-st, J-C
O. rigida	1									10		12				16		*	*	*	S-E, YS, DR
O. robusta	1																				YS
O. setigera								8				12	13					*	*		S-E, CJ
O. similis	1	2	3				7	8				12			15	16	*	*	*	*	S-E, JH, MS, KY, PS, YS, J-C
O. tenuis								8										*	*		CJ
Oncaea conifera	1											12			15	16		*	*		S-E, YS, J-C
O. media															15					*	J-C
O. venusta	1	2	3				7					12	13		15	16	*	*	*	*	S-E, MS, KY, PS, YS, K-st, J-C
Paracyclopina nana															15		*	*	*		J-C
Sapphirina intestinata													13					*			S-E
HARPACTICOIDA																					
Clytemnestra rostrata	1											12			15	16	*	*		*	S-E, YS, J-C
C. scutellata	1											12				16		*			S-E, YS
Euterpina acutifrons			3				7			10		12	13		15	16	*	*	*	*	S-E, MS, KY, J-C, DR
Harpacticus uniremis										10										*	DR
Macrosetella gracilis	1											12	13					*			S-E, YS, J-C
Microsetella norvegica	1		3				7			10		12			15		*	*	*	*	S-E, KY, YS, J-C, DR
M. rosea	1											12			15	16	*	*	*		S-E, YS, JH
Miracia efferata										10										*	DR
Monstrilla longiremis										10					15	16		*	*		J-C, S-E, DR
Setella gracilis										10					15	16		*	*	*	J-C, S-E, DR
Tigriopus japonicus										10					15	16	*	*	*	*	JC, S-E, DR
Tisbe ensifera										10										*	DR

S: South Sea, JH: Jinhae Bay, KY: Kwangyang Bay, S-E: Southeastern sea, YS: Yeosu, MS: Masan Bay, CJ: Chejudo, PS: Pusan, NK: Naktong river estuary, TS: Tsushima Is., K-st: Korea Strait, J-C: Coastal waters of Jinhae and Chungmu, DR: Deukryang Bay
1: Shim and Ro(1982), 2: Park(1956), 3: Kim(1984), 4: Park *et al.*(1990), 5: Yoo *et al.*(1991), 6: Kang(1988), 7: Lee(1989), 8: Lim(1989), 9: Kim(1985), 10: KORDI(1981), 11: Kang(1992), 12: Shim *et al.*(1982), 13: Hue(1967), 14: KORDI(1982), 15: Park and Lee(1982), 16: Lee(1972)

to discriminate *C. sinicus* from other similar species.

Abundance and distributional pattern

Copepod populations in the study area showed great temporal and spatial variations in abundances, varied from about 10 individuals/m^3 to more than 100,000 individuals/m^3. In general, temporal variations of copepod abundance in the coastal waters were more distinct than those of the offshore waters. For example, copepod abundances, collected with a Bongo net(250-μm mesh size) in the offshore waters around Cheju Island(Fig. 1), ranged from about 100 individuals/m^3 to more than 3,000 individuals/m^3 during November to December, 1986 (KORDI, 1987), about 20 individuals/m^3 up to 500 individuals/m^3 during October to November, 1987 (KORDI, 1988), about 20 individuals/m^3 to about 100 individuals/m^3 during February to March, 1988 (KORDI, 1988), less than 10 individuals/m^3 to more than 500 individuals/m^3 in August, 1988(KORDI, 1989), and from about 10 individuals/m^3 to more than 1,000 individuals/m^3 during March to April, 1989(KORDI, 1989).

Copepod abundances, however, collected using a Marugawa net(150-μm mesh size) in the coastal waters such as Jinhae Bay, sometimes exceeded more than 396,000 individuals/m^3(KORDI, 1980). Average copepod abundances, collected using a Clarke-Bumpus sampler with a 158-μm mesh net in Kwangyang Bay, ranged from about 1,000 individuals/m^3 to more than 2,500 individuals/m^3 in March, 1982, about 300 individuals/m^3 to more than 5,000 individuals/m^3 in July and October, 1982, and about 1,000 individuals/m^3 to 2,000 individuals/m^3 in December, 1982(Kim, 1984). These abundances were lower than those reported in the embayments (Yeoja Bay, Gamagyang Bay, and Yeosuhae Bay) near Kwangyang Bay, where copepod abundances varied from more than 2,000 individuals/m^3 up to more than 11,000 individuals/m^3(Shim and Ro, 1982). Maximal copepod abundances reported in the previous studies are listed in Table 2 with mesh size that was used in sampling.

Although direct comparisons of copepod abundances between two areas, i.e., offshore waters around Cheju Island and the coastal embayments, were not possible because of differences in the

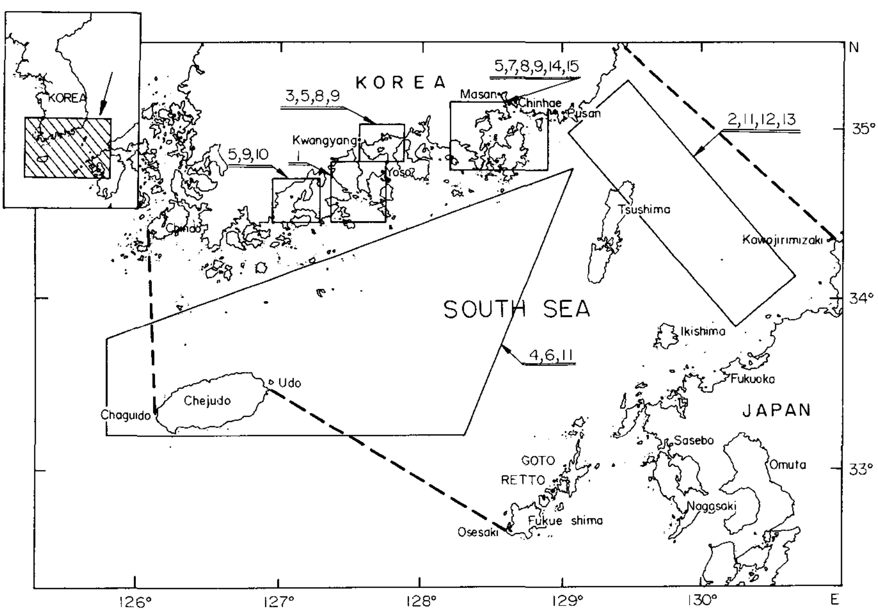

Fig. 1. A map showing the study area. Dotted lines show the boundaries of the South Sea of Korea. Numbers in the map designate the numbers of references in Table 1.

mesh-size of the net used for collecting zooplankton, copepod abundances in the embayments were generally higher than those in the offshore waters. The trend of "higher copepod abundance in the coastal waters and lower abundance in the offshore waters" was also observed in the Korea Strait(Fig. 2; modified from Figure IV-3. in KORDI, 1992). This distributional pattern was well matched with that of phytoplankton abundance(KORDI, 1992), which implied that food resources could be one of the important factor to determine the distributional pattern of copepods in the South Sea.

Seasonal variations in abundance

There were distinct seasonal variations in the copepod abundance. Lee(1972) reported that copepod populations in Jinhae Bay reached maximal abundance in April 1967, when *Oithona similis* was most abundant, and that copepod populations decreased continuously after the April peak, reaching minimal abundance in August, and then increased again to the second peak in September. Two abundance peaks of copepods were also found in Masan Bay in spring and fall(Lee, 1989; see Fig. 3). Other studies, however, reported the maximal abundances

Table 2. Maximal copepod abundances previously reported in the South Sea of Korea

Total copepod abundances	mesh size	references*
up to about 15,000 indvs./m^3	160 μm	1
NA	333 μm	2
up to about 17,400 indvs./m^3	158 μm	3
NA	330 μm	4
NA	200 μm	5
NA	?	6
up to about 50,000 indvs./m^3	200 μm	7
NA	200 μm	8
NA	various	9
up to average 48,082 indvs./m^3	240 μm	10
NA	240 μm	11
up to 10,100 indvs./m^3	160 μm	12
NA	330 μm	13
up to 338,000 indvs./m^3	150 μm	14
up to 7,900 indvs./m^3	330 μm	15
up to 45,580 indvs./m^3	330 μm	16
up to 396,500 indvs./m^3	150 μm	17**

* References from 1 to 16 are in the footnote of Table 1.
17**: KORDI(1980), NA: not available

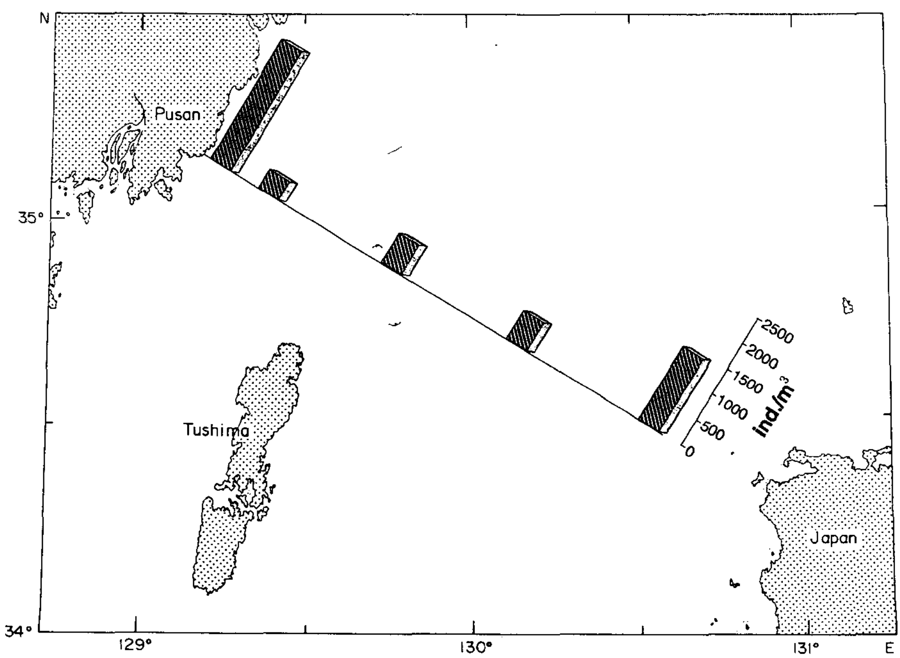

Fig. 2. Spatial distribution pattern of copepod abundances across the Korea Strait in April, 1992.(modified from Fig. Ⅳ-3. in KORDI, 1992).

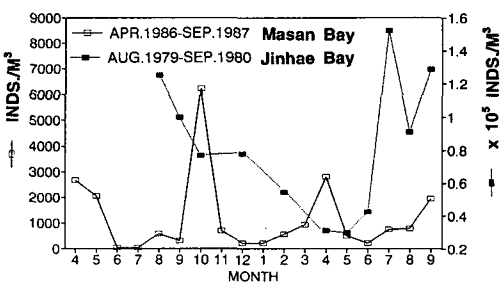

Fig. 3. Seasonal variations of copepod abundances in the coastal waters of the South Sea.(Data of Masan Bay from Lee, 1989; Jinhae Bay from KORDI, 1980).

in summer. For example, KORDI(1980) and Kim (1984) reported that copepods were most abundant in July(Fig. 3; modified from Fig. IV-19 in KORDI, 1980) in Jinhae Bay and in Kwangyang Bay, respectively.

Kang and Lee(1991) showed that bimodal biomass peaks of zooplankton in spring and fall were typical seasonal pattern in the Yellow Sea, and unimodal biomass peak of zooplankton, more than 90 % of which were copepods, in fall was the pattern in the South Sea(see Fig. 3 in Kang and Lee, 1991). Maximal abundances of copepods in fall were also observed in the embayments near Yeosu (Shim and Ro, 1982). Such differences in the seasonal variations of zooplankton biomass between the Yellow Sea and the South Sea were attributed to the differences of the seasonal variations in phytoplankton biomass between two areas(Kang and Lee, 1991).

In general, there were two different seasonal patterns of copepod populations in the South Sea such as bimodal abundance peaks in spring and fall, and unimodal abundance peak in summer or fall. Annual variations in the seasonal pattern of copepod abundance, however, were sometimes significant even in the same area(Lee, 1989). Temporal variations in copepod abundance could be explained by two different viewpoints of "bottom-up control" and "top-down control"(Kim *et al.*, 1992). Food source availability is an example of the "bottom-up control" and predation by planktivores such as gelatinous macrozooplankton and larval fish on copepods is an example of the "top-down control". Because these two controls influence on copepod populations simultaneously, both controls should be considered to study copepod population dynamics.

Indicator species

The water mass of the South Sea is known to be affected by a branch of the Kuroshio Current which transfers warm and saline waters, thus this area has very complex hydrological characteristics, which may influence on the distributional pattern of planktonic organisms. The distributional pattern of copepods in relation to temperature and salinity was investigated in the different water masses of the South Sea, and studies on the indicator species of copepods in the South Sea have been actively conducted. For example, Park *et al.*(1990) reported *Acartia clausi* and *Centropages abdominalis* as the indicator species of neritic cold waters(but see Kim, 1985 for *A. clausi*), *Temora discaudata* and *Centropages furcatus* as the indicator species of neritic warm waters, and *Pleuromamma gracilis*, *Undinula darwini*, *Calocalanus plumulosus*, and *Calanopia elliptica* as the indicator species of oceanic warm waters.

Oceanic warm-water copepods were further classified into two kinds of indicator species of the Tsushima current by Kang(1992). One group, including *Nannocalanus minor*, *Cosmocalanus darwini*, *Eucalanus subtenuis*, *Eucalanus crassus*, *Euchaeta plana*, *Euchaeta concinna*, *Euchaeta marina*, and *Scolecithrix danae*, occurred in the offshore waters between Cheju Island and Tsushima Island when the water temperature was over 13~14℃ in winter and spring, and over 20℃ in summer and fall. The other group, including *Canthocalanus pauper*, *Undinula vulgaris*, *Calocalanus pavo*, *Calocalanus plumulosus*, *Acrocalanus longicornis*, and *Acrocalanus gracilis*, did not occur in winter and spring, however, distributional pattern was similar to the former group in summer and fall.

The use of copepods as indicator species of various water masses with their geographical distribution would be valuable to determine the movements of particular water masses. In the South Sea, where hydrological conditions are very complex, indicator species reported in the previous studies are useful as "biological indicators" of water transport.

Suggestion for future studies

As reviewed above, taxonomy and ecological information about species composition, abundance, and distributional pattern of copepods in the South Sea have been relatively known in detail. The information on the role of copepods in the planktonic ecosystem and physiology of copepods is also important to understand ecology of copepod population, however, such information is very limited. Therefore, in future studies, trophic interactions(e.g., Kim *et al.,* 1992), grazing(e.g., Kim and Chang, 1992; Shin and Choi, 1992), excretion(e.g., Park, 1986), vertical migration(e.g., Park, 1990), and reproduction should be intensively investigated for further understanding of copepods.

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韓國 南海에 出現하는 橈脚類에 關한 考察

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한국 남해에서 출현하는 요각류에 대한 현재까지 발표된 분류학과 생태학 논문들을 대상으로, 요각류의 종조성, 개체수, 분포, 계절변화 등을 검토하였다. 그 결과 총 179종의 요각류가 동정되었으며, 연안역과 내만역의 우점종들은 *Acartia clausi, Paracalanus parvus, Oithona similis, Oithona nana* 등이었고, 이는 제주도 부근의 외양에서 발표된 우점종들과는 상이하였다. 또한 이 논문에서는 남해에 출현하는 지표종들에 관해서도 토의를 하였다. 요각류의 개체수는 일반적으로 외양역보다는 연안역에서 최대 평균 390,000개체/m^3 이상으로 높게 나타났다. 한편 요각류의 계절별 개체수 변화에는, 주로 춘계와 추계에 각각 개체수 극대치가 나타나는 유형과, 하계에서 추계에 걸쳐 극대치가 나타나는 두가지 유형이 있는 것으로 나타났다.