The Journal of the Oceanological Society of Korea
Vol. 27, No. 2, pp. 112-122, June 1992

Taxonomic Studies on Brackish Copepods in Korean Waters. I Redescription of *Tortanus dextrilobatus* Chen and Zhang, 1965 from Korean Waters, with Remarks on Zoogeography of the subgenus *Eutortanus*

SUSUMU OHTSUKA[1], YANG HO YOON[2] AND YUKIHIRO ENDO[3]
[1]*Fisheries Laboratory, Hiroshima University, Takehara, Hiroshima 725, Japan*
[2]*Department of Oceanography, Yosu National Fisheries University, Yosu 550-749, Korea*
[3]*Faculty of Applied Biological Science, Hiroshima University, Higashi-Hiroshima 724, Japan*

韓國產 汽水性 橈脚類의 分類學的 硏究 I 韓國에 있어서 未記錄種 *Tortanus dextrilobatus* Chen and Zhang, 1965 記載와 *Eutortanus* 亞屬의 地理分布에 대하여

大塚攻[1]・尹良湖[2]・遠藤幸宏[3]
[1]廣島大學 生物生產學部 附屬水產 實驗所
[2]麗水水產大學 海洋學科
[3]廣島大學 生物生產學部

The calanoid copepod *Tortanus* (*Eutortanus*) *dextrilobatus* Chen and Zhang, 1965, which had been recorded only from South China, is redescribed from brackish waters in South Korea. The diagnosis of the little known subgenus *Eutortanus* is presented here. The zoogeography of five species of *Eutortanus* is also discussed.

韓國 南部의 汽水域에서, 지금까지는 中國南部에서만 出現報告가 있는 calanoid 橈脚類 *Tortanus dextrilobatus* Chen and Zhang, 1965가 發見되었기에, 여기에 韓國產 未記錄種으로 記載한다. 아울러, 本種의 屬하는 *Eutortanus*亞屬의 標徵을 記述함과 동시에, 이들 亞屬種들의 分布에 대한 動物地理學的인 考察을 實施하였다.

INTRODUCTION

Since Korean brackish copepods have never been investigated in detail, we have just started to study the taxonomy and zoogeography of the copepods. During these studies, *Tortanus dextrilobatus* Chen and Zhang, 1965 (Calanoida: Tortanidae) was found in the lower Somjin River, South Korea. This species had been so far recorded only in Chinese waters: Amoy and its environs (coastal regions of Kwangtung Province) (Chen and Zhang, 1965); the Chaikiang River (Shen and Lee, 1966). Although Kim (1985) had intensively studied the marine calanoid copepod fauna in Korean waters, only three species of *Tortanus*, *T. discaudatus* (Thompson and Scott, 1897), *T. forcipatus* (Giesbrecht, 1889) and *T. spinicaudatus* (Shen and Bai, 1956) have so far been reported.

Tortanus dextrilobatus belongs to the little known subgenus *Eutortanus* Smirnov, 1935 which consists

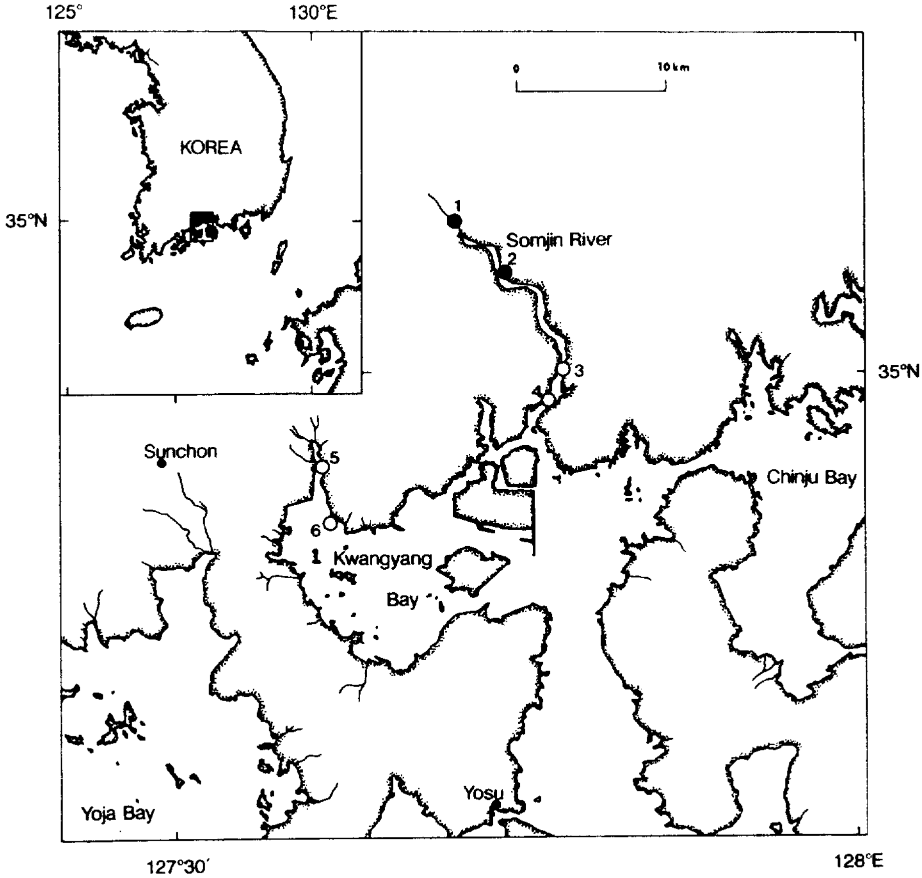

Fig. 1. Location of plankton collection. Solid circle: station where *Tortanus dextrilobatus* was found; open circle: station where *T. dextrilobatus* was not collected.

of five northeastern Asian species (Ohtsuka, in press). The occurrences of the subgenus (*T. dextrilobatus*, *T. sheni* Hulsemann, 1988, *T. spinicaudatus* Shen and Bai, 1956, *T. vermiculus* Shen, 1955) are restricted to Chinese and Korean waters except for *T. derjugini* Smirnov, 1935 which is relatively widely distributed in the northwestern Pacific coastal waters including the Sea of Okhotsk, the Sea of Japan and the Ariake Sea (Brodsky, 1950; Chen and Zhang, 1965; Tanaka, 1965; Shen and Lee, 1966).

The present paper covers the redescription of *T. dextrilobatus* collected from the Somjin River since this species had not been fully described by Chen and Zhang (1965). The diagnosis of the subgenus *Eutortanus* is presented here and the zoogeography of *Eutortanus* is discussed.

MATERIALS AND METHODS

Tortanus dextrilobatus was found in plankton samples from two stations in the Somjin River, South Korea on 18 December 1991 (Fig. 1). All specimens of this species were collected with small conical plankton nets (diameter 30 cm, mesh size 0.09 mm) from the shore. The plankton nets were obliquely towed from the near-bottom to the surface at each station (depth ca. 2~3 m). The sample was fixed in 10 % neutralized formalin/*in-situ* water immediately after capture. Both surface water temperature (mercury thermometer) and salinity (water collected with the plankton nets, Mohr Method) were also recorded at each station (Table 1). The morphological terminology of copepods in this paper is based on that used by Huys and

Table 1. Surface water temperature and salinity at each station.

Station	Surface water temperature(℃)	Salinity (‰)
1	8.7	0.14
2	7.1	3.53
3	8.6	16.76
4	9.5	19.81
5	9.5	11.10
6	9.4	30.07

Boxshall (1991).

TAXONOMIC DESCRIPTION

Genus *Tortanus* Giesbrecht, 1898

Subgenus *Eutortanus* Smirnov, 1935

Diagnosis. – Prosome of female approximately twice as long as urosome. Fourth and 5th pedigerous somites of both sexes completely or incompletely fused. Fifth pedigerous somite of female produced posterolaterally into triangular process whereas that of male produced posteriorly into blunt process. Urosome of female relatively short, 3- or 4-segmented; anal somite incompletely fused with caudal rami. First abdominal somite of male without process on the right side. Right caudal rami of both sexes slightly longer than left; caudal anterolateral seta modelately long. Maxillulary arthrite with 12 setae and 1 setule. Coxa of maxilliped with 5 setae. Endopod of leg 1 3-segmented; distal exopod segments of legs 1 and 2 with 2 and 3 outer spines, respectively; distal endopod segments of legs 2, 3 and 4 having 8, 8 and 6 setae, respectively. Both legs 5 of female 3-segmented; left leg slightly longer than right; distal segment tapering distally, its inner margin fringed with hairs. Penultimate segment of right leg 5 of male considerably expanded inward, accompanied with 1 inner medial process and with or without inner subterminal triangular process; distal segment of right leg 5 moderately or extremely elongate; basis and exopod segments of left leg relatively short.

Type species. – *Tortanus derjugini* Smirnov, 1935

Tortanus (*Eutortanus*) *dextrilobatus* Chen and Zhang, 1965

Materials examined – 4 ♀♀, 14 ♂♂. All specimens were collected from Stn. 1 and Stn. 2 in the Somjin River, South Korea (see Fig. 1 and Table 1).

Description. – Females (Figs 2, 3 and 4-A~D). Body (Fig.1-A, B) robust, widest at posterior end of cephalosome. Body length ranging from 1.74 to 1.79 mm (mean± standard deviation=1.77±0.02 mm, number of individuals examined=4). Prosome about 2.4 times as long as urosome (Fig. 1-A). Eye large, reddish in color. Cephalosome with dorsal transverse groove medially and dorsal median protuberance posteriorly. Fourth pedigerous somite almost completely fused with 5th one, whose suture line slightly visible in lateral view; posterior ends of 5th pedigerous somite produced posterolaterally into triangular process; tips of processes slightly different in shape. Urosome (Fig. 2-C~G) 3-segmented; genital double somite as long as wide; genital operculum (Fig. 2-H) located ventromedially, semicircular with posterior middle margin slightly concave; 2nd urosomal somite with posterior dorsal protuberance on right side; 3rd urosomal somite having large, irregular dorsolateral process on anterior right side; anal somite incompletely fused with left caudal ramus and almost completely with right one; right caudal ramus slightly longer than left one.

Antennule (Fig. 3-A) reaching to middle of 3rd urosomal somite; 17-segmented, ancestral segments II to IX, XI to XIII, and XXVI to XXVIII fused. Armature elements as follows: I-1, II-IX-8+2 aesthetascs, X-1, XI-XIII-4+1 aesthetasc, XIV-2+1 aesthetasc, XV-1, XVI-2+1 aesthetasc, XVII-2+1 aesthetasc, XVIII-2+1 aesthetasc, XIX-2+1 aesthetasc, XX-2, XXI-2+1 aesthetasc, XXII-1, XXIII-1, XXIV-1+1, XXV-1+1+1 aesthetasc, XXVI-XXVIII-6+1 aesthetasc. Antenna (Fig. 2-I) with coxa and basis partly fused; coxa having small medial seta; basis with 2 medial setae of unequal lengths; basis and endopod completely fused; endopod 2-segmented, proximal segment with 1 seta and row of spinules subterminally, distal segment with 6 setae terminally and row of spinules subterminally; exopod 3-segmented, proximal segment unarmed, middle segment having 3 setae, distal segment with

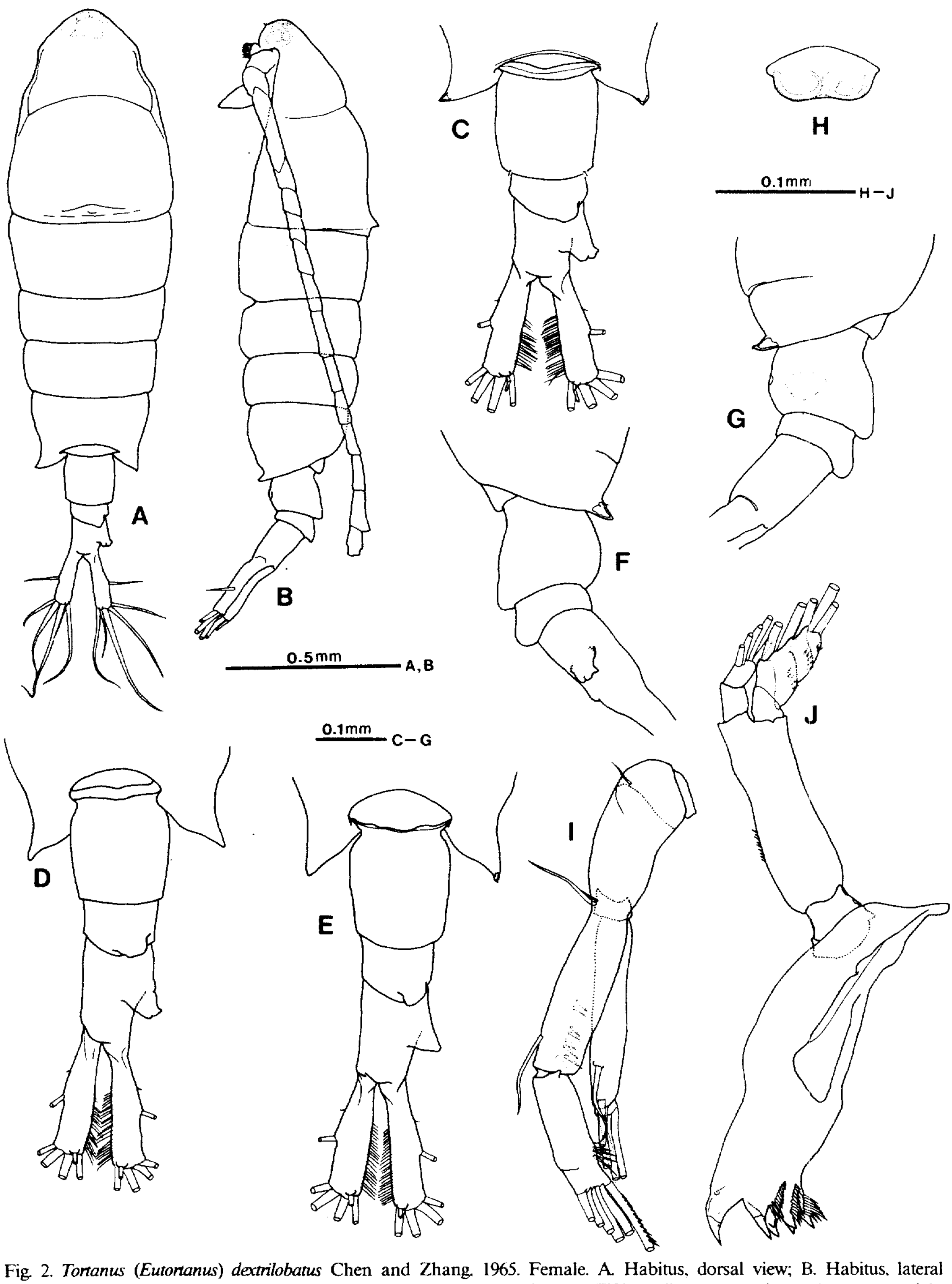

Fig. 2. *Tortanus* (*Eutortanus*) *dextrilobatus* Chen and Zhang, 1965. Female. A. Habitus, dorsal view; B. Habitus, lateral view; C-E. Fifth pedigerous somite and urosome, dorsal view; F. Fifth pedigerous somite and urosome, right lateral view; G. Fifth pedigerous somite and urosome, left lateral view; H. Genital operculum; I. Antenna; J. Mandible.

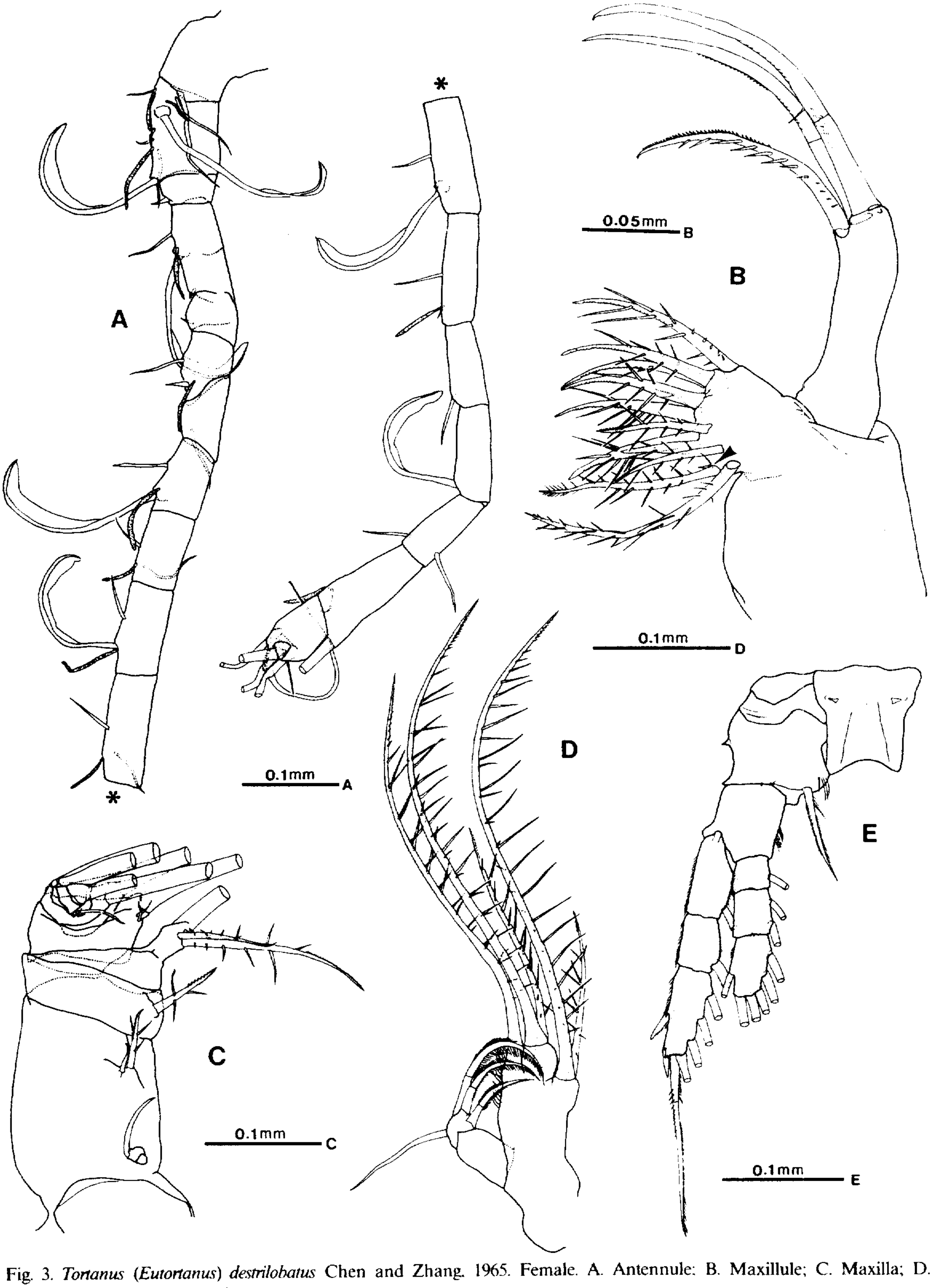

Fig. 3. *Tortanus* (*Eutortanus*) *derjugini* Chen and Zhang, 1965. Female. A. Antennule; B. Maxillule; C. Maxilla; D. Maxilliped; E. Leg 1.

2 terminal setae. Mandible (Fig. 2-J): gnathobase with 5 cusped teeth, 2 ventralmost and dorsalmost of which monocusped and the remaining 2 teeth bicusped; basis elongate with patch of small spinules along medial inner margin; endopod 2-segmented, proximal segment without seta, distal segment with 5 setae; exopod with 5 segments incompletely fused, bearing 3 rows of minute spinules. Maxillule (Fig. 3-B) with basis, endopod and exopod completely absent; praecoxal arthrite stout, bearing 12 spinulose setae and 1 minute setule (indicated by arrowhead); coxal endite with 3 stout, spinulose setae terminally. Maxilla (Fig. 3-C) developed; proximal and distal endites of praecoxa and coxa having 1, 2, 1 and 3 setae, respectively; basal endite with 1 developed and 2 minute setae. Setal formula of endopod given as follows: 1, 2, 2, 2. One seta on 2nd endopod segment rudimentary. Maxilliped (Fig. 3-D). Setal formula of praecoxal and coxal endites: 0, 2, 2, 1. Basis unarmed; endopod 1-segmented, bearing 3 inner plumose setae and 1 outer seta.

Seta and spine formula of legs 1 to 4 (Fig. 3-E, 4-A~C) as follows.

	coxa	basis	exopod segment 1 2 3	endopod segment 1 2 3
Leg 1	0-1	0-0	0-1;0-1;II,1,4	0-1;0-2;1,2,3
Leg 2	0-1	0-0	I-1;I-1;III,I,5	0-3;2,2,4
Leg 3	0-1	0-0	I-1;I-1;III,I,5	0-3;2,2,4
Leg 4	0-1	1-0	I-1;I-1;III,I,5	0-3;1,2,3

Distal endopod segments of legs 2 to 4 with row of minute spinules on anterior surface. Leg 5 (Fig. 4-D) 3-segmented; both coxal segments fused to form a common base; basis with small seta at point three-fourth outer margin; exopod 1-segmented; endopod absent; left exopod slightly longer than right; exopod with row of hairs along inner margin; outer margin without prominences.

Males (Figs 4-E~G, 5-A, B). Body (Fig. 4-E) much slenderer than that of the female. Body length ranging from 1.53 to 1.76 mm (1.63±0.07 mm, n=13). Prosome ca. 1.7 times as long as urosome (Fig. 4-E). Fourth and 5th pedigerous somites incompletely fused (see Fig. 4-F); posterior corner of 5th pedigerous somite produced posteriorly into blunt process. Urosome (Fig. 4-F, G) 5-segmented; genital somite with opening on left lateral side; 1st abdominal somite longest, with 2 relatively stout sensilla ventrolaterally (indicated by arrows in Fig. 4-F); anal somite separate from caudal rami; right caudal ramus slightly longer than left; posterior half inner borders of caudal rami fringed with hairs.

Right antennule (Fig. 5-A) geniculate, indistinctly 16-segmented but consisting of 14 fully separated segments; geniculation between 14th and 15th segments; ancestral segments I to VII, X to XII, XXI to XXIII, and XXIV to XXVIII fused. Armature element as follows: I-VII-8+2 aesthetascs, VIII-1, IX-2, X-1, XI-2+1 aesthetacs, XII-unarmed, XIII-unarmed, XIV-2+1 aesthetasc, XV-1, XVI-2+1 aesthetasc, XVII-1+1 aesthetasc, XVIII-1+1 aesthetasc, XIX-1+1 aesthetasc, XX-2, XXI-XXIII-2+1 aesthetasc, XXIV-XXVIII-10+2 aesthetascs. Ninth segment expanded dorsally to form sheath concealing half the preceding segment; 14th segment with proximal, low process and serrate ridge along anterior margin; 15th segment having 2 serrate, anterior ridges and distal blunt process.

Leg 5 (Fig. 5-B): right and left coxal segments fused to form a common base as in the female. Right leg: basis and 1st exopod segment fused to form expanded segment with medial and subterminal processes along inner margin and seta on posterior surface; the subterminal process bearing small seta on the base; distal exopod segment smoothly curved inwards, bearing proximal and medial setules, 4 short, shout spines and 24~25 ridges along inner margin; distal half the segment slenderer than proximal. Left leg: basis with outer seta subterminally; proximal exopod segment with short, thick spine subterminally; distal exopod segment with tuft of hairs and small seta on proximal inner margin, tuft of spinules along distal inner margin, and 1 medial inner and 2 terminal short spines; terminal outer portion with 13 transverse and 3 longitudinal ridges.

Variation—The dorsolateral process on the right side of the third urosomal somite of the female

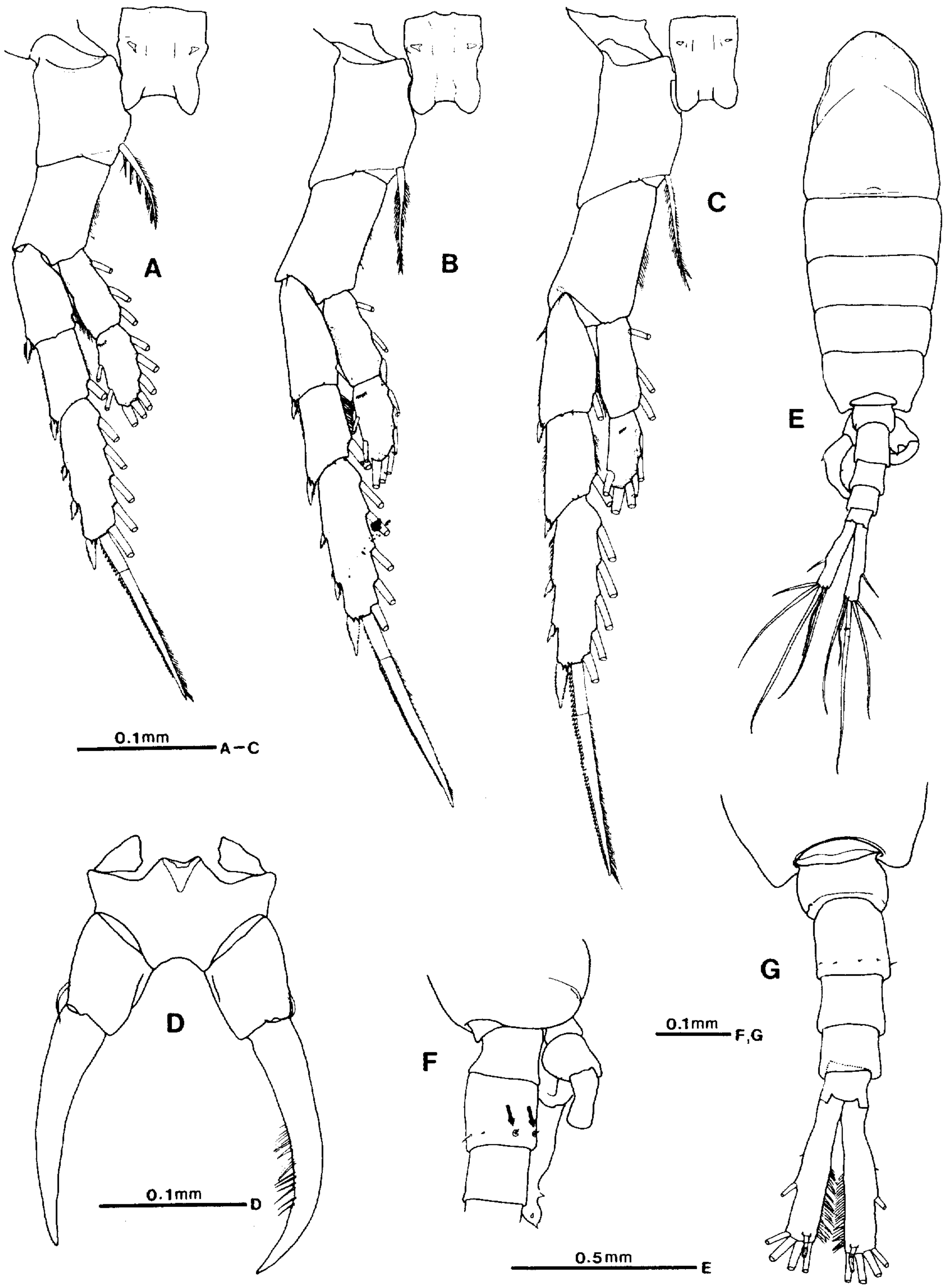

Fig. 4. *Tortanus* (*Eutortanus*) *dextrilobatus* Chen and Zhang, 1965. Female (A~D) and Male (E~G). A. Leg 2, anterior surface; B. Leg 3, anterior surface; C. Leg 4, anterior surface; D. Leg 5, anterior surface; E. Habitus, dorsal view; F. Fifth pedigerous somite and urosome, right lateral view, relatively stout sensilla indicated by arrows; G. Fifth pedigerous somite and urosome, dorsal view.

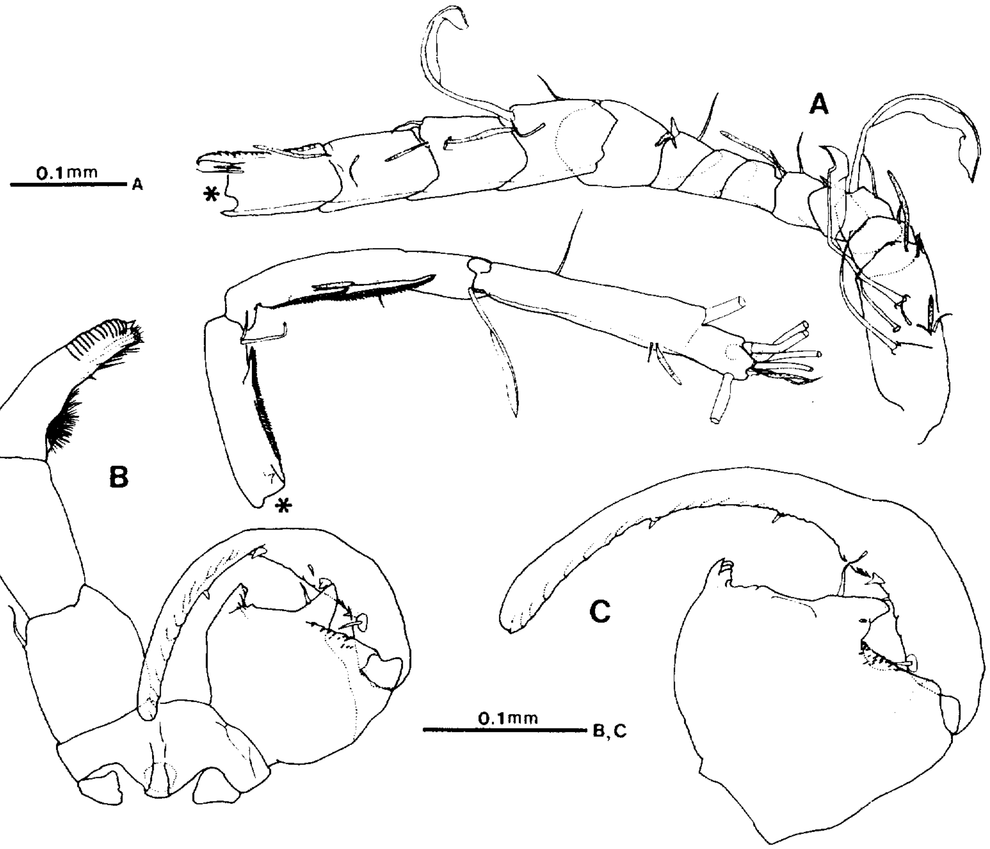

Fig. 5. *Tortanus* (*Eutortanus*) *dextrilobatus* Chen and Zhang, 1965, Male (A, B) and *T.* (*E.*) *derjugini* Smirnov, 1935, Male from the Ariake Sea (C). A. Right antennule; B. Leg 5, anterior surface; C. Exopod segments of right leg 5, anterior surface.

is slightly variable in shape (see Fig. 2-C~E): the tip is irregularly (Fig. 2-C, D) or smoothly produced (Fig. 2-E). The number of the ridges along the inner margin of right leg 5 of the male is 24 or 25 in the present study (number of individuals examined=3).

Remarks—Chen and Zhang (1965) reported that *Tortanus dextrilobatus* from the type locality, Amoy, is 2.00~2.25 mm in body length in female and 2.00~2.05 mm in male (present study: female: 1.74~1.79 mm; male: 1.53~1.76 mm), and that the fifth pedigerous somite of the female is fused with the fourth and symmetrically produced. However, the present specimens of the female have incompletely fused fourth and fifth pedigerous somites and slightly asymmetrical distal corners of the fifth pedigerous somite. In males from the Somjin River, the numbers of ridges on the outer margin of the distal exopod segment of left leg 5 and on the inner margin of the distal exopod segment of right leg 5 are 13 and 24~25, respectively, whereas those from Amoy are 9~10 and 19~21, respectively. In addition, *T. dextrilobatus* commonly occurs in warm seasons in Amoy (Chen and Zhang, 1965). These may suggest morphological and ecological differences between populations in Amoy and in South Korea.

Tortanus dextrilobatus is most closely related to *T. derjugini* in having the following synapomorphic characters in the subgenus: 3-segmented urosome in female and elongated, distal segment of right leg 5 in male. The most distinctive character to distinguish *T. dextrilobatus* from *T. derjugini* is the development of the dorsolateral process on the

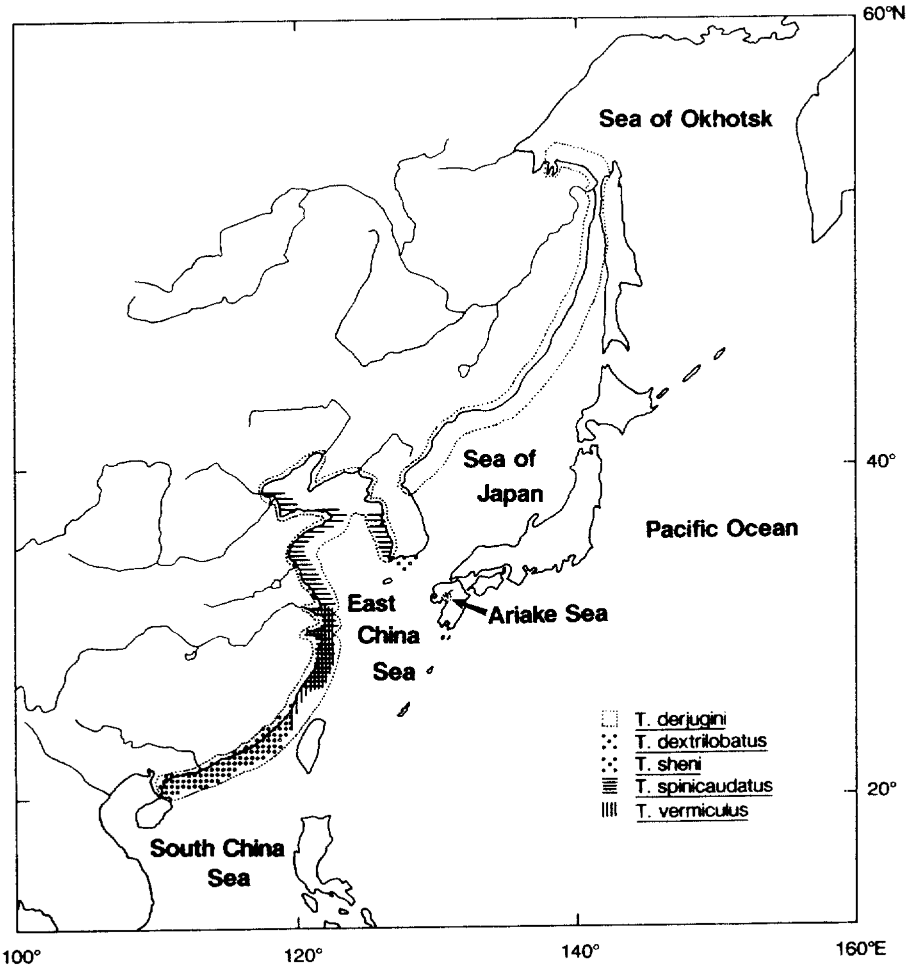

Fig. 6. Schematic illustration of distribution patterns of five species of the subgenus *Eutortanus* (*Tortanus derjugini*, *T. dextrilobatus*, *T. sheni*, *T. spinicaudatus*, *T. vermiculus*).

third urosomal somite of the female: the process is considerably developed in *T. dextrilobatus* but weakly in *T. derjugini*. The dorsolateral process of female *T. derjugini* had been overlooked in the previous studies (Smirnov, 1935; Brodsky, 1950; Chen and Zhang, 1965). It is difficult to discriminate male *T. dextrilobatus* from male *T. derjugini*. Chen and Zhang (1965) mentioned that there were several differences between these two males in the shapes of cephalosme, abdomen and leg 5. However, the reexamination of male *T. derjugini* from Japanese, Korean and Chinese waters revealed that these differences are not useful enough to distinguish between these two males. There are differences in the structure of right leg 5 (see Fig. 5-B, C): the chela is much smaller in *T. dextrilobatus* than in *T. derjugini*; the second segment is larger and relatively wider in *T. derjugini* than in *T. dextrilobatus*.

Occurrence—The occurrence of *Tortanus dextrilobatus* seems to be restricted to brackish waters of low salinity (see Fig. 1 and Table 1). Such a distributional pattern as in *T. dextrilobatus* in the Somjin River is similar to that in another brackish calanoid copepod *Sinocalanus sinensis* (Poppe, 1889) in the Ariake Sea: *S. sinensis* has a restricted distribution in the mouth of rivers discharging into the Ariake Sea (salinity 1.6~2.9‰) (Hiromi and Ueda, 1987). However, *T. dextrilobatus* occurred in waters of higher salinity (24.00~25.54‰) in the mouth of the Chaikiang River, South China (Shen and Lee, 1966).

ZOOGEOGRAPHY OF THE SUBGENUS *EUTORTANUS*

The schematic distributions of five species belonging to the subgenus *Eutortanus* (*Tortanus derjugini, T. dextrilobatus, T. sheni, T. spinicaudatus, T. vermiculus*) are illustrated in Fig. 6 based on Smirnov (1935), Brodsky (1950), Shen (1955), Shen and Bai (1956), Chen and Zhang (1965), Tanaka (1965), Shen and Lee (1963, 1966), Cheng et al. (1978), Kim (1985), and our present and unpublished data. The four species except for *T. derjugini* have restricted distributions along Chinese and West and South Korean coasts whereas *T. derjugini* is widely distributed from the Sea of Okhotsk (Smirnov, 1935; Brodsky, 1950) through the Sea of Japan (Brodsky, 1950; Chen and Zhang, 1965) to the East China Sea and South China Sea (Chen and Zhang, 1965; Tanaka, 1965; Cheng et al., 1978; Lian, personal communication). *T. spinicaudatus, T. vermiculus, T. dextrilobatus* and *T. sheni* have parapatric or sympatric distributions along the Chinese coast: *T. spinicaudatus* occurs exclusively on the coasts of the Yellow Sea, Pohai and the northern East China Sea (Shen and Bai, 1956: Chen and Zhang, 1965; Kim, 1985); *T. vermiculus* is distributed along the southern part of the East China Sea along with *T. spinicaudatus; T. dextrilobatus* and *T. sheni* have a sympatric distribution along the coast of the South China Sea. The discontinuous distribution pattern of *T. spinicaudatus* seems to reflect sampling efforts: this species is likely to be distributed along the whole coasts of Pohai and the Yellow Sea. *T. dextrilobatus* and *T. derjugini* have isolated distributions in the Somjin River, South Korea (present study) and in the Ariake Sea (Tanaka, 1965; Ueda, personal communication), respectively.

The distributional patterns of five species of *Eutortanus* definitely correspond to the East Asian initial endemic element defined by Nishimura (1980, 1981). According to Nishimura (1981), this element would have originated from the ancient East China Sea which might have been a huge gulf with low salinity water from the Middle Miocene to the Pleistocene. The speciation of these five brackish or neritic species (Brodsky, 1950; Shen and Bai, 1956; Shen and Lee, 1963, 1966; Chen and Zhang, 1965) could have occurred in this gulf. The introduction and isolation of *Tortanus derjugini* in the Sea of Okhotsk, the Sea of Japan and the Ariake Sea might be explained as follows. Only *T. derjugini* may have been distributed in the northernmost part of the ancient East China Sea (the present Yellow Sea and its neibouring waters in western Kyushu) before around 60,000 years ago. *T. derjugini* may have been introduced from the ancient East China Sea into the Sea of Japan during 20,000~60,000 years ago, in particular, 20,000~30,000 years ago when cold, low-salinity continental waters had flown into the Sea of Japan through the Tsushima Channel (Ohba, 1983; Takayashu, personal communication), and expanded its distribution northward after the event. Later, the population of *T. derjugini* in the Sea of Okhotsk, the Sea of Japan and the Ariake Sea could have been isolated from the Chinese continental population by the Jômonian transgression (6,000~10,000 years ago) in the same manner as proposed by Hiromi and Ueda (1987) for a continental relict *Sinocalanus sinensis* in the Ariake Sea. Considering the absence of *T. dextrilobatus* from the Sea of Okhotsk, the Sea of Japan and the Ariake Sea, the population of *T. dextrilobatus* in South Korea may have been relatively recently (after the Jômonian transgression) introduced from the southern Chinese population by ships (cf. Hiromi and Ueda, 1987), migratory birds (Semura et al., 1986) or other dispersal mechanisms.

ACKNOWLEDGEMENTS

We express our sincere thanks to Dr. K. Hulsemann (Biologische Anstalt Helgoland) for her critical reading of the manuscript. We are also grateful to Dr. K. Takayasu (Shimane University) for his precious comments on the zoogeography of

Eutortanus, and to Dr. H. Hashimoto (Hiroshima University) and students of the Department of Oceanography, Yosu National Fisheries University for cooperation at the sampling stations and in the laboratory. Thanks are due to Dr. H. Ueda (University of Ryukyu), Dr. S.W. Kim (Korea Sports Science University) and Dr. G. Lian (Third Institute of Oceanography, China) for giving us specimens of *Tortanus derjugini* collected from the Ariake Sea, the Yellow Sea and the East China Sea.

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Revision accepted April 30, 1992