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TORTANUS (*ATORTUS*) (COPEPODA: CALANOIDA) OF SOUTHERN JAPANESE WATERS, WITH DESCRIPTION OF TWO NEW SPECIES, *T.* (*A.*) *DIGITALIS* AND *T.* (*A.*) *RYUKYUENSIS*, AND DISCUSSION ON DISTRIBUTION AND SWARMING BEHAVIOR OF *ATORTUS*

Susumu Ohtsuka and Katsunori Kimoto

ABSTRACT

Five species of *Tortanus* (*Atortus*) (Copepoda: Calanoida) were collected from shallow waters in Shijiki Bay, Shibushi Bay, and the Ryukyu Islands, South Japan, among which two are newly described. They are: *T.* (*A.*) *digitalis*, new species, *T.* (*A.*) *erabuensis*, *T.* (*A.*) *longipes*, *T.* (*A.*) *rubidus*, and *T.* (*A.*) *ryukyuensis*, new species. The subgenus *Atortus* is distributed mainly in tropical or subtropical coastal waters in the Indo-West Pacific region, and each species seems to have a restricted distribution. Twelve of the 16 known species of *Atortus* are assigned to 4 species groups based on morphological characters and distribution patterns. Direct observations by SCUBA diving revealed that some species of *Atortus* form swarms near the bottom, at least during the daytime.

Copepods of the genus *Tortanus* Giesbrecht (Calanoida: Tortanidae) mainly inhabit tropical or subtropical coastal waters. Twenty-two species are known from the Indo-Pacific region and three from the Atlantic Ocean (Bowman, 1971; Chen, 1983; González and Bowman, 1965; Kim, 1985; Othman, 1987; Ohtsuka *et al.*, 1987b; Steuer, 1926). The subgenus *Atortus* Sewell which consists of 14 species, including three species from Japan, are recorded only from the Indo-West Pacific region (Ohtsuka *et al.*, 1987b; Tanaka, 1965).

Five species of *Atortus* including two new species are included in the present study carried out in South Japan. This paper deals with the description of two new species of *Atortus* from the Ryukyu Islands and the previously unknown females of *T.* (*A.*) *rubidus* from Shijiki Bay, Hirado Island, together with the redescription of males of this species. Relationships among species of the subgenus *Atortus* and their distribution are also discussed.

Observations by SCUBA diving revealed that some species of *Atortus* formed swarms near the sea bottom during the daytime (Kimoto *et al.*, 1988). The present paper reports the microdistribution of *Atortus* near the bottom in Shijiki Bay.

MATERIALS AND METHODS

Sampling stations, collection dates, and gear used are shown in Fig. 1 and Table 1. Qualitative samples of zooplankton were collected at all stations except for Shijiki Bay. At the inner part of Shijiki Bay, a bilevel plankton net (Kimoto *et al.*, 1988) was employed by SCUBA diving to examine the microdistribution of copepods near the sea bottom. The net was towed along a 50-m graduated nylon rope stretched on sandy bottom, rocky bottom with small brown algae, and eelgrass beds of 2–6 m depth.

TWO MORPHOLOGICAL GROUPS OF THE SUBGENUS *ATORTUS*

The subgenus *Atortus* can be divided into two morphological groups (Bowman, 1971). The first group (=the *tropicus* group sensu Othman, 1987) is characterized by (1) the urosomal segment 2 of the male with a process on the right side, (2) the anterior end of the serrate margin of the eighteenth segment of right antenna 1 of the male produced proximally over the seventeenth segment, and (3) the distal segment of leg 5 of the female either slender and asymmetrical or subquadrate. The second group (=the *murrayi* group sensu Othman, 1987) is featured by (1) the absence of a lateral process on the right side of urosomal segment 2 of the male, (2) the eighteenth segment of the right antenna 1 of the male not produced proximally, and (3) leg 5 of the female ending in three prongs. In the second group the males can be characterized as above, whereas the characters of females do not apply to all of them and should therefore be revised as follows: leg 5 of the female 3-segmented, its terminal segment tapering distally and furnished with 1–3 distal prongs.

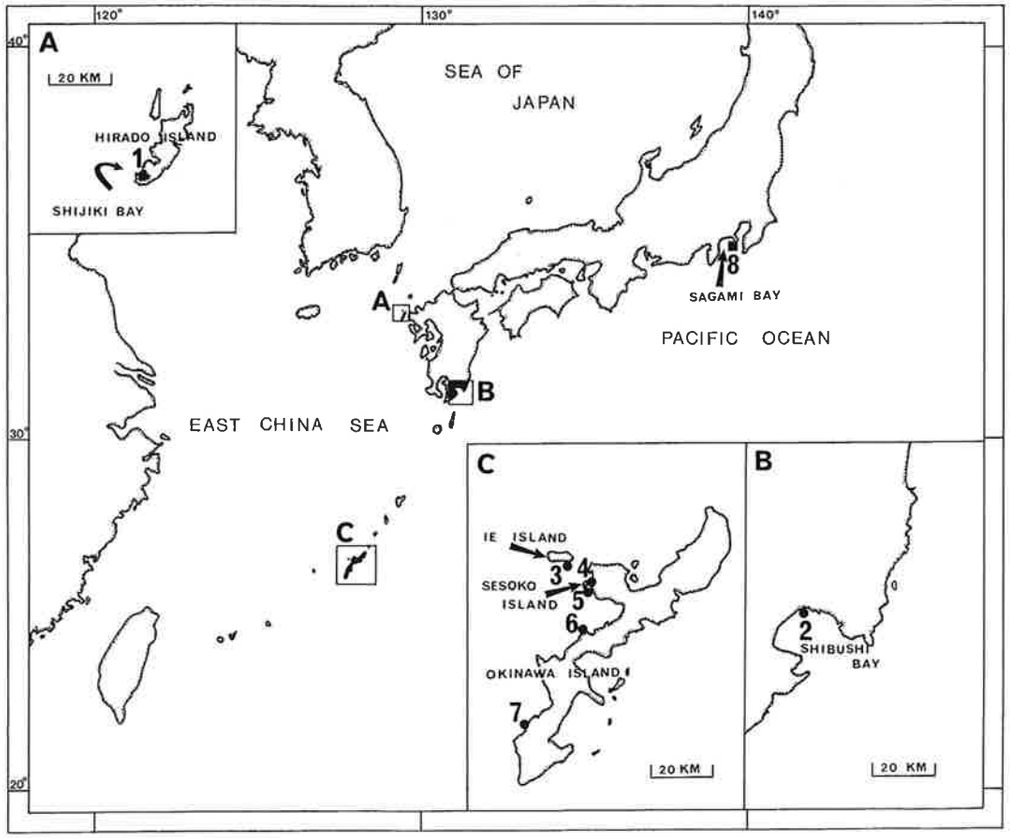

Fig. 1. The locations of sampling stations for *Tortanus* in South Japan. 1, Shijiki Bay, Hirado Island; 2, Shibushi, Shibushi Bay; 3, south coast of Ie Island; 4, Motobu Harbor, Okinawa Island; 5, east coast of Sesoko Island; 6, Ahuso River mouth, Okinawa Island; 7, Aja Harbor, Okinawa Island; 8, Aburatsubo, Sagami Bay (the type locality of *Tortanus rubidus*).

The first group is composed of *T. bowmani* Othman, *T. brevipes* Scott, *T. giesbrechti* Jones and Park, *T. longipes* Brodsky, *T. rubidus* Tanaka, *T. tropicus* Sewell, and the two new species which are described here. The second group consists of *T. bonjol* Othman, *T. capensis* Grindly, *T. erabuensis* Ohtsuka, Fukuura, and Go, *T. lophus* Bowman, *T. murrayi* Scott, *T. recticauda* (Giesbrecht), *T. scaphus* Bowman, and *T. sinicus* Chen.

Tortanus (*Atortus*) *ryukyuensis*, new species
Figs. 2–4

Material Examined.—Ie Island: 7 ♀♀ (length 2.15 (mean) ± 0.07 mm (standard deviation), range 2.08–2.26 mm), 9 ♂♂ (length 1.78 ± 0.07 mm, range 1.66–1.88 mm). Afuso River mouth, Okinawa Island: 1 ♀ (length 2.14 mm), 1 ♂ (length 1.78 mm).

Types.—All types taken from Ie Island are deposited in the National Science Museum, Tokyo. Holotype: ♀, dissected and mounted on slides, NSMT-Cr 9437. Paratypes: 2 ♀♀, dissected and mounted on slides, NSMT-Cr 9438 and 9439; 3 ♂♂, dissected and mounted on slides, NSMT-Cr 9440 to 9442; 3 ♀♀ and 3 ♂♂, whole specimens, NSMT-Cr 9443.

Description of Female.—Body (Fig. 2A): cephalosome and first pediger separated. Eye protuberance (Fig. 2B) anteriorly produced. Posterior corners of pediger 5 symmetrical, rounded. Urosome (Fig. 2C, D): genital segment slightly asymmetrical, produced laterally at one-third length on left side; genital operculum (Fig. 2E) oval and located at one-third length; anal segment completely fused with caudal rami; caudal rami nearly symmetrical. Antenna 1 (Fig. 2F) reaching end of caudal rami; segments 1–12 completely or incompletely fused. Armature of seg-

Table 1. Sampling stations in southern Japan, collection dates, and gear used.

Stations	Dates	Local time	Gear used
Shijiki Bay (33°11′N, 129°24′E)	10–13 July 1984	0855–1551	Near-bottom towings with hand-nets by SCUBA diving (2–6 m deep)
Shibushi (31°27′N, 130°52′E)	23 January 1985	2130–2215	Towings around lights for collecting fishes
Ie Island (26°42′N, 127°48′E)	10 May 1988	1430–1630	Near-bottom towings with hand-nets by SCUBA diving (1.5 m deep)
Motobu Harbor, Okinawa (26°38′N, 127°53′E)	10 May 1988	2238	Oblique towings with a NORPAC net from a quay
Sesoko Island (26°38′N, 127°52′E)	12 May 1988	Daytime	Near-bottom towings with hand-nets by SCUBA diving (5–7 m deep)
Afuso River mouth, Okinawa (26°30′N, 127°51′E)	8 July 1987	Daytime	Surface towings with a Marukawa net (1 m deep)
Aja Harbor, Okinawa (26°15′N, 127°41′E)	14 January 1983	Daytime	Vertical towings with a Kitahara net from a quay

ments 13–23 same as in *T. scaphus* (Bowman, 1971, table 1). Antenna 2 (Fig. 2G): endopod incompletely fused with basipod 2; proximal segment of endopod with terminal setule and subterminal patch of spinules, apical segment bearing 6 terminal setae and subterminal patch of spinules. Exopod 2-segmented; apical segment furnished with 4 terminal setae and subterminal setule. Mandibular blade (Fig. 2H) with 5 cusps; teeth 3 and 4 bifurcate at tip. Mandibular palp (Fig. 2I) with 2-segmented endopod and 4-segmented exopod; segments 3 and 4 of exopod incompletely fused. Maxilla 1 (Fig. 2J): gnathobase (first inner lobe) with 12 setae and setule; second inner lobe bearing 3 large terminal setae. Maxilla 2 (Fig. 3A) stout, distalmost seta of endopod without usual clawlike tip. Maxilliped (Fig. 3B) with distally produced basipod 1 having 2 stout spinulose setae; basipod 2 cylindrical, bearing subterminal spinules on inner margin; endopod with 3 thick plumose setae and 1 naked seta directed outward. Legs 1–4 (Fig. 3C–F) with 2-segmented endopods and 3-segmented exopods. Leg 5 (Fig. 3G, H) rudimentary: proximal segments of right and left legs fused to form common base; apical segment lamellar, bearing seta at midlength of outer margin.

Description of Male.—Body (Fig. 4A) more slender than that of female; posterior corners of pediger 5 symmetrical, rounded, and produced posteriorly to about proximal one-third of genital segment. Urosome (Fig. 4B, C): genital segment slightly asymmetrical, produced posterolaterally on left side; second segment furnished with posterolateral and posteroventral processes (Fig. 4D, E) of unequal size on right side, each bearing small setule; anal segment partly fused with caudal rami; caudal rami symmetrical. Right antenna 1 (Fig. 4F) geniculate: serrate ridge of eighteenth segment produced proximally to midlength of seventeenth segment. Leg 5 (Fig. 4G–I). Right leg: basipod broad without armament; exopodal segment 1 with middle prominence bearing terminal setule and large square platelike projection on inner distal margin; exopodal segment 2 elongate and strongly curved inward at midlength to form claw. Left leg: basipod 1 with inner proximal depression; basipod 2 elongate with middle inner and subterminal outer setules; exopod segment 2 smoothly curved inward with 2 inner setules of unequal length, 2 outer minute and 1 terminal setules; distal end of exopod segment 2 with patch of small granules.

Remarks.—Females of the five species belonging to Bowman's (1971) first group (*T. bowmani, T. brevipes, T. longipes, T. rubidus, T. ryukyuensis*) have a reduced leg 5 with two lamellate terminal segments. The posterolateral corners of pediger 5 are symmetrical in *T. ryukyuensis,* but asymmetrical in the four other species. *Tortanus bowmani* and *T. ryukyuensis* have nearly symmetrical caudal rami and a similar genital segment. However, spermatophores of these two species are different in the shape of two vanes extending on right and left

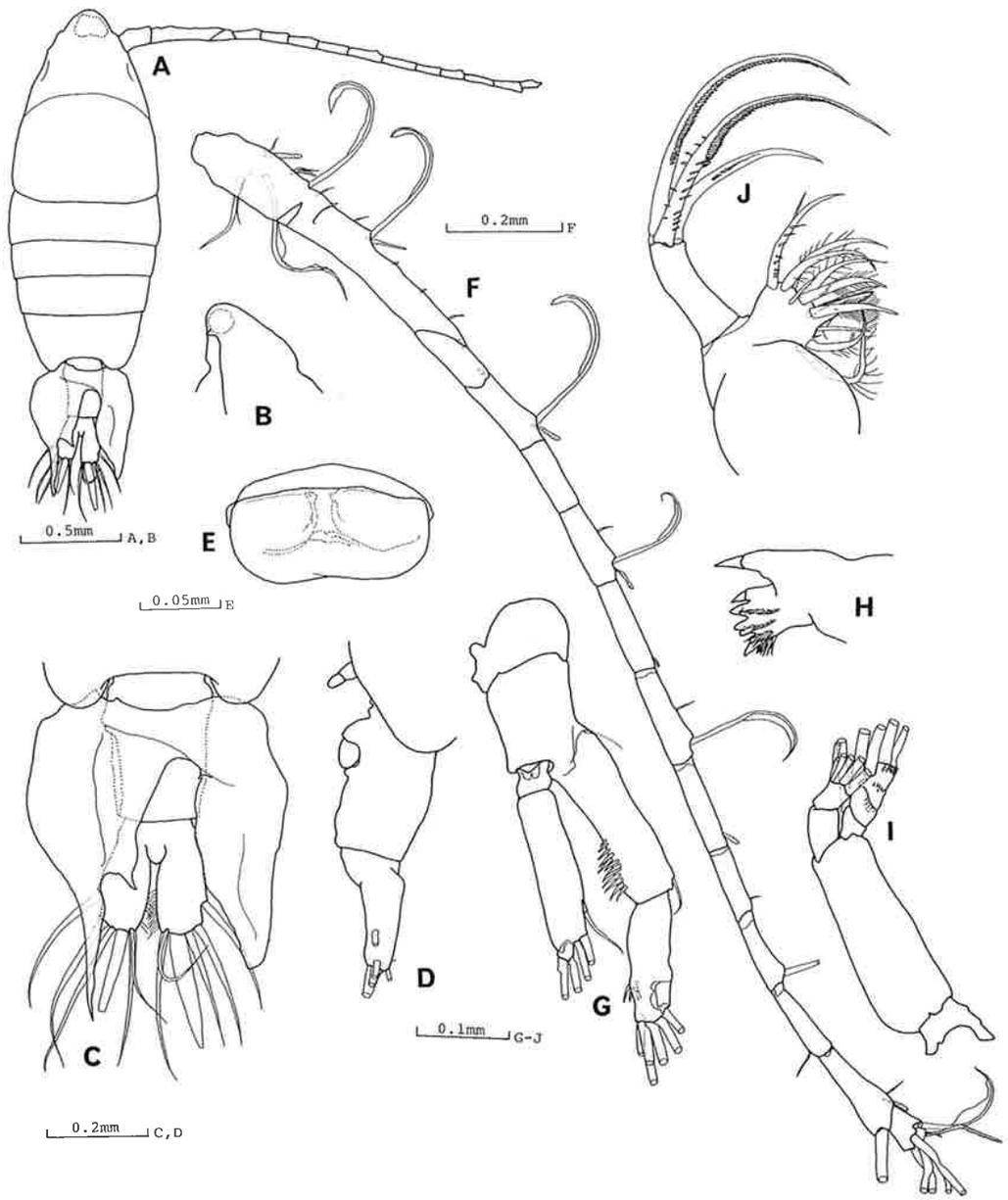

Fig. 2. *Tortanus* (*Atortus*) *ryukyuensis,* new species. Female (holotype). A, habitus, dorsal view; B, eye protuberance, lateral view; C, fifth pediger and urosome, dorsal view; D, same, lateral view, spermatophore omitted; E, genital operculum; F, antenna 1; G, antenna 2; H, mandibular gnathobase; I, mandibular palp; J, maxilla 1.

sides of the genital segment: those of the latter are longer than those of the former, extending beyond the caudal rami. The male of the present species is unique in the group by having a right leg 5 with an inner distal platelike projection on the proximal exopod segment.

Etymology.—The specific name *ryukyuensis* is named after the Ryukyu Islands, where it was collected.

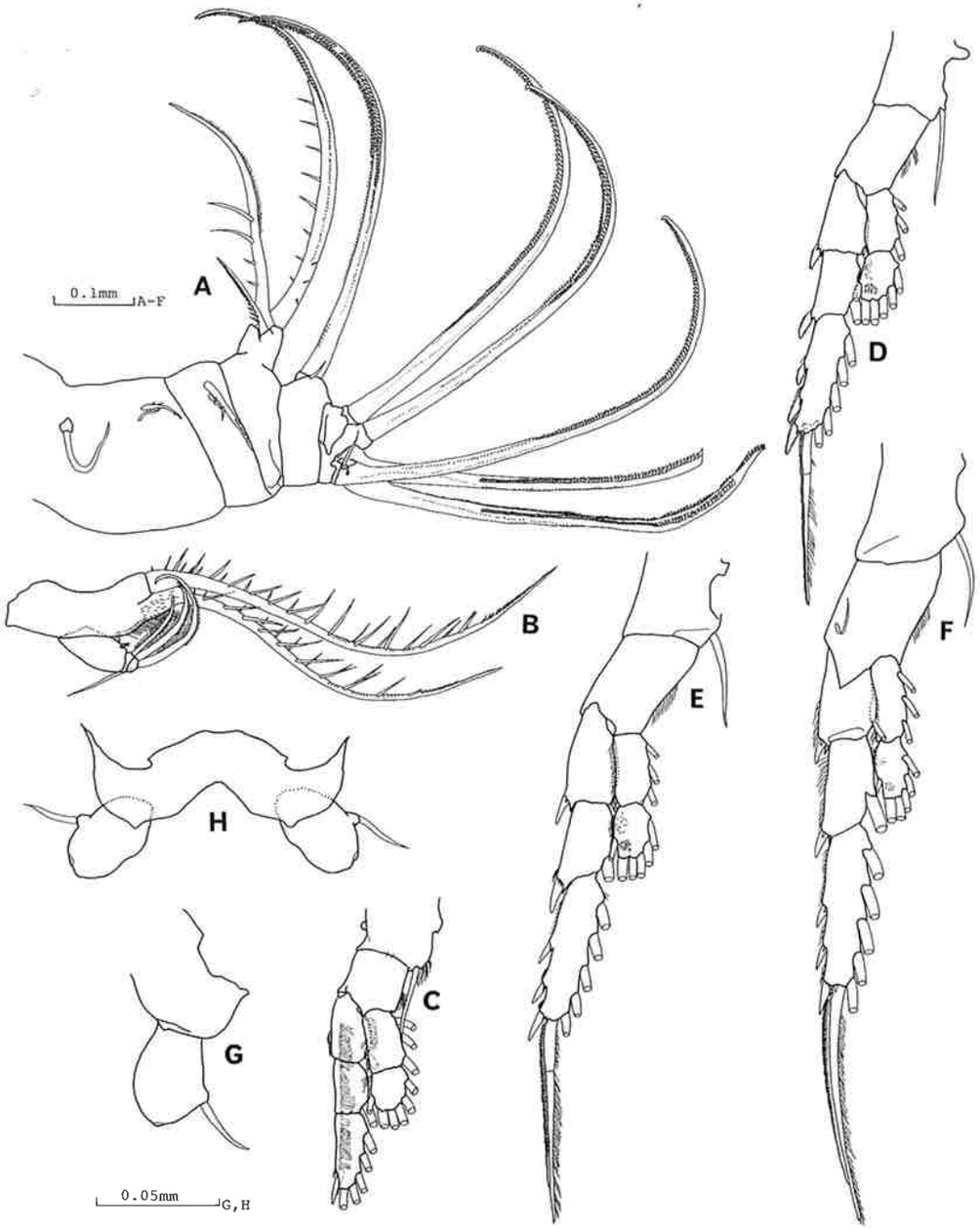

Fig. 3. *Tortanus* (*Atortus*) *ryukyuensis,* new species. Female (holotype: B–G; paratype: A, H). A, maxilla 2; B, maxilliped; C, leg 1; D, leg 2; E, leg 3; F, leg 4; G, H, leg 5.

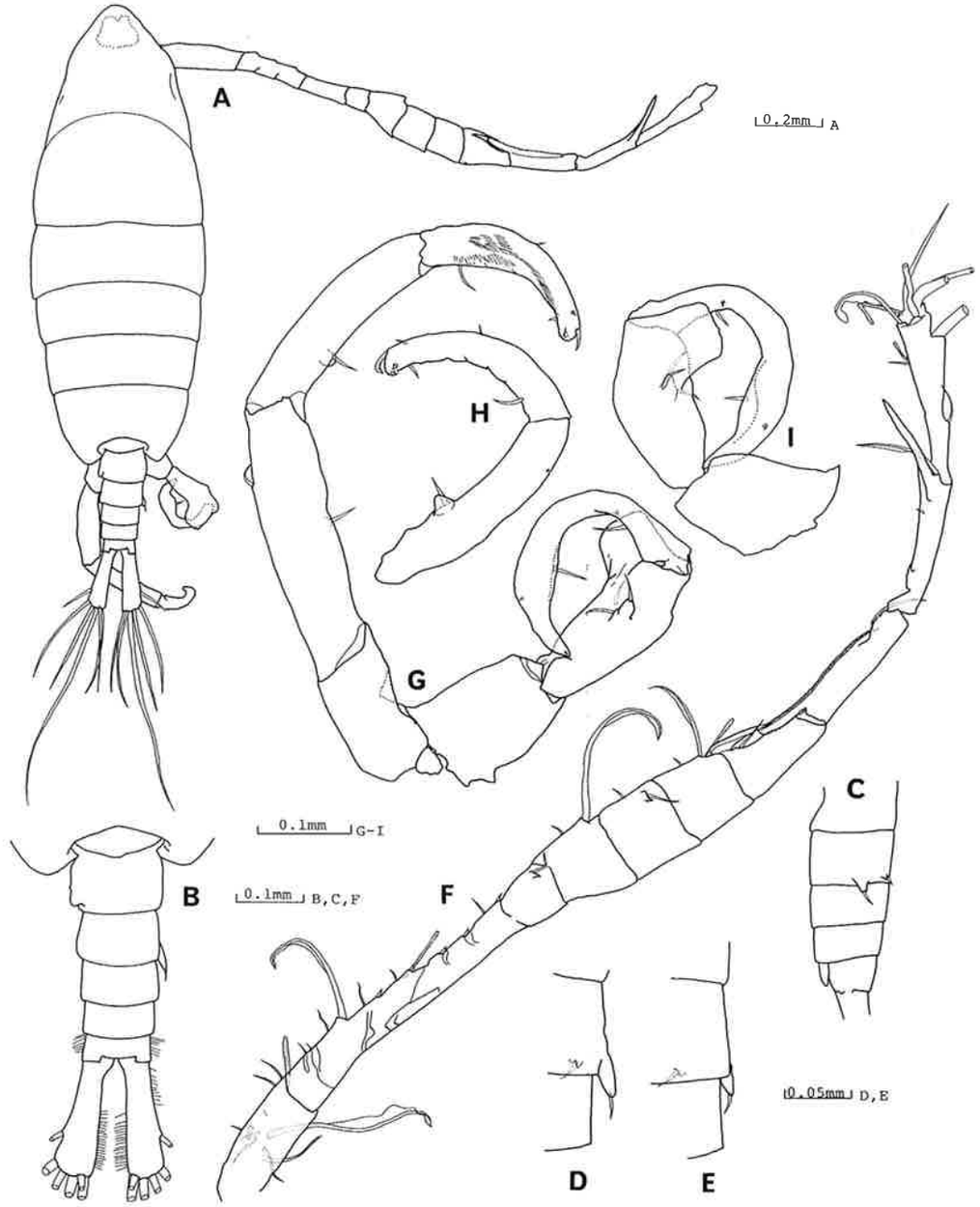

Fig. 4. *Tortanus* (*Atortus*) *ryukyuensis,* new species. Male (paratypes). A, habitus, dorsal view; B, fifth pediger and urosome, dorsal view; C, urosome, lateral view; D, E, lateral process of right side of second urosomal segment; F, right antenna 1; G, leg 5, anterior view; H, terminal two segments of left leg 5, posterior view; I, right leg 5, posterior view.

Distribution (Fig. 10).—This new species has been collected only from Ie and Okinawa Islands (present record).

Tortanus (*Atortus*) *digitalis*, new species
Figs. 5, 6

Material Examined.—Aja Harbor, Okinawa Island: 4 ♀♀ (length 2.79 ± 0.04 mm, range 2.74–2.84 mm). Motobu Harbor, Okinawa Island: 1 ♂ (length 1.96 mm). Sesoko Island: 1 ♂ (length 1.82 mm).

Types.—The female holotype and paratypic females and paratypic males were collected from Okinawa Island, and Okinawa and Sesoko Islands, respectively. They are deposited in the National Science Museum, Tokyo. Holotype: ♀, dissected and mounted on slides, NSMT-Cr 9444. Paratypes: 1♀, dissected and mounted on slides, NSMT-Cr 9445; 2 ♂♂, dissected and mounted on slides, NSMT-Cr 9446 and 9447.

Description of Female.—Body (Fig. 5A) similar to female of *T. rubidus* described below (Fig. 7A). Posterior ends of pediger 5 asymmetrical, right side (Fig. 5E, F) with irregular low ventrolateral process, left side (Fig. 5C, D) with irregularly produced ventrolateral lobe. Urosome (Fig. 5B, C, G) 2-segmented: right side of genital segment with 2 dorsolateral and 1 ventrolateral processes anteriorly and large slender pointed projection at midlength; genital field elevated, and genital operculum oblique to sagittal plane of segment; posterior half of genital segment bearing numerous minute granules ventrally; anal segment fused with caudal rami; caudal rami asymmetrical. Antenna 1 (Fig. 5H) similar to that of *T. ryukyuensis* in structure and armature. Leg 5 (Fig. 5I, J) 2-segmented, slightly asymmetrical; distal segment lamellate, incompletely fused with proximal segment, bearing outer terminal seta.

Description of Male.—Body (Fig. 6A) similar to male of *T. rubidus* (Fig. 9A). Right lateral process (Fig. 6B–D) of urosomal segment 2 not reaching end of following segment. Right antenna 1 (Fig. 6E): proximal process of segment 17 reaching distal end of segment; serrated ridge of segment 18 produced proximally over one-third of segment 17. Leg 5 (Fig. 6F, G). Right leg: basipod furnished with blunt inner subterminal papilla; exopod segment 1 bearing large inner middle projection with 2 setules along proximal margin, distal half of segment broadened and curved inward; exopod segment 2 slightly curved inward and middle part of inner margin emarginate. Left leg: basipod 1 with inner proximal pocket; basipod 2 elongate, about twice as long as basipod 1; exopod segment 1 with fingerlike process, nearly half as long as segment, internally close to proximal end.

Remarks.—This new species is most closely related to *T. rubidus* in sexually modified characters, i.e., leg 5 and genital segment of the female (Fig. 7C, D, F); right antenna 1 and leg 5 of the male (Figs. 8B, 9F–H). The new species is, however, distinguished in the female from *T. rubidus* by the number of processes on the right side of the genital segment. In the male it is different from *T. rubidus* in (1) the serrate ridge of segment 18 of the right antenna 1 and (2) the inner process of exopod segment 1 of left leg 5.

Etymology.—The specific name *digitalis* is derived from the elongate, fingerlike, inner process of exopod segment 1 of the male left leg 5.

Distribution (Fig. 10).—The species is recorded only around Okinawa Island (present record).

Tortanus (*Atortus*) *rubidus* Tanaka, 1965
Figs. 7–9

Material Examined.—Shijiki Bay: 2 ♀♀ (length 2.37, 2.33 mm), 13 ♂♂ (length 1.99 ± 0.06 mm, range 1.92–2.11 mm). Shibushi: 2 ♂♂ (length 2.02, 2.10 mm). Sagami Bay: 1 ♂ (one of the syntypes collected by Dr. O. Tanaka).

Description of Female.—Body (Fig. 7A): corners of pediger 5 (Fig. 7B, C) asymmetrical, left side longer than right and reaching about proximal one-fourth of genital segment. Urosome (Fig. 7B–D) 2-segmented; genital segment asymmetrical; right side with small dorso- and ventrolateral processes directed outward and large medial lateral projection produced; genital field produced at one-third length of segment; posterior half of segment bearing numerous minute granules ventrally; anal segment fused with caudal rami; caudal rami asymmetrical, left ramus slightly larger than right ramus. Antenna 1 (Fig. 7E) same in structure and armature as those of *T. scaphus* and *T. ryukyuensis*. Leg 5 (Fig. 7F) similar in structure to that of *T. ryukyuensis* but terminal segment of left leg incompletely fused with proximal segment.

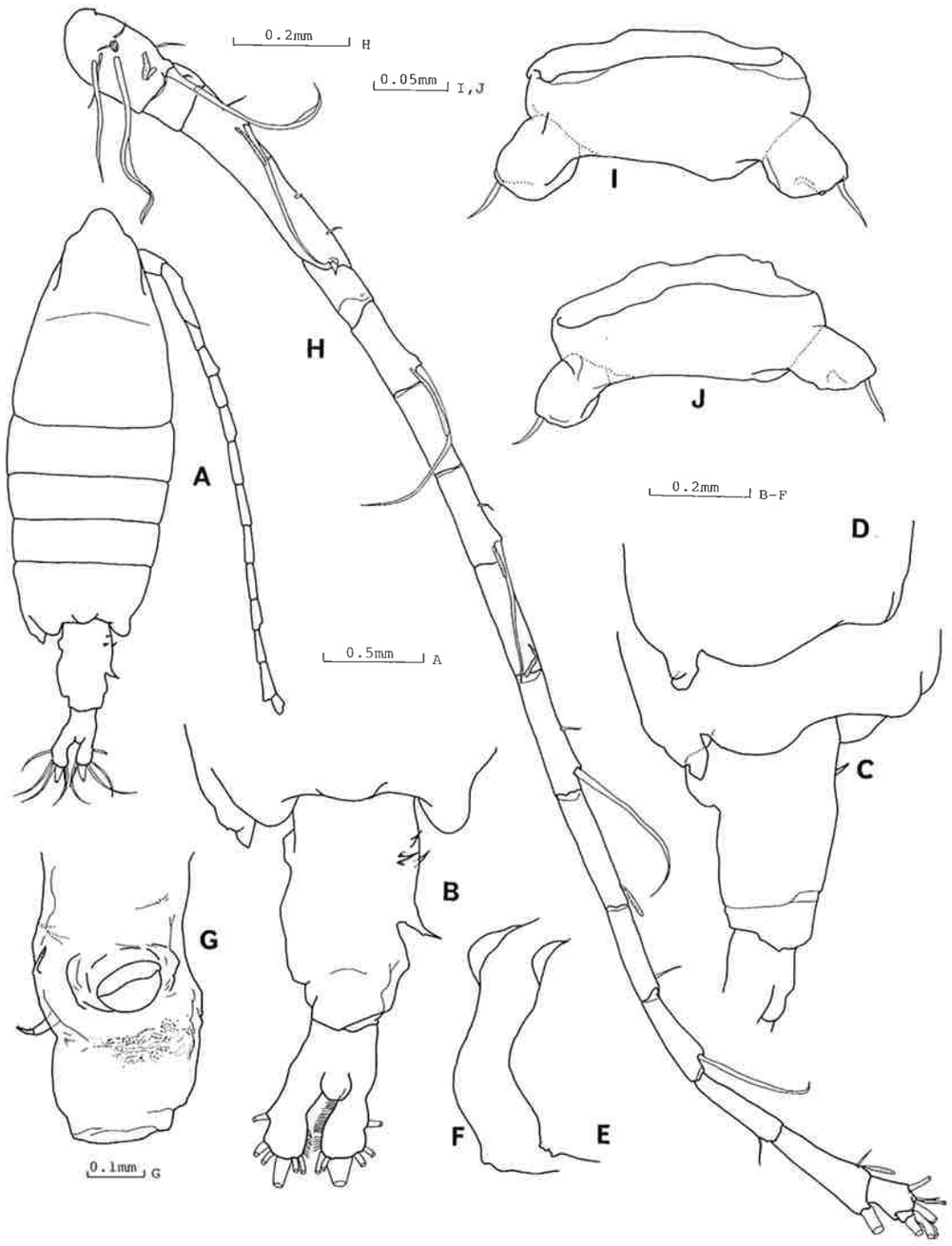

Fig. 5. *Tortanus* (*Atortus*) *digitalis*, new species. Female (holotype: A–C, E, H, I; paratype: D, F, G, J). A, habitus, dorsal view; B, fifth pediger and urosome, dorsal view; C, same, left lateral view; D, fifth pediger, left lateral view; E, F, same, right lateral view; G, genital segment, ventral view; H, antenna 1; I, J, leg 5, posterior view.

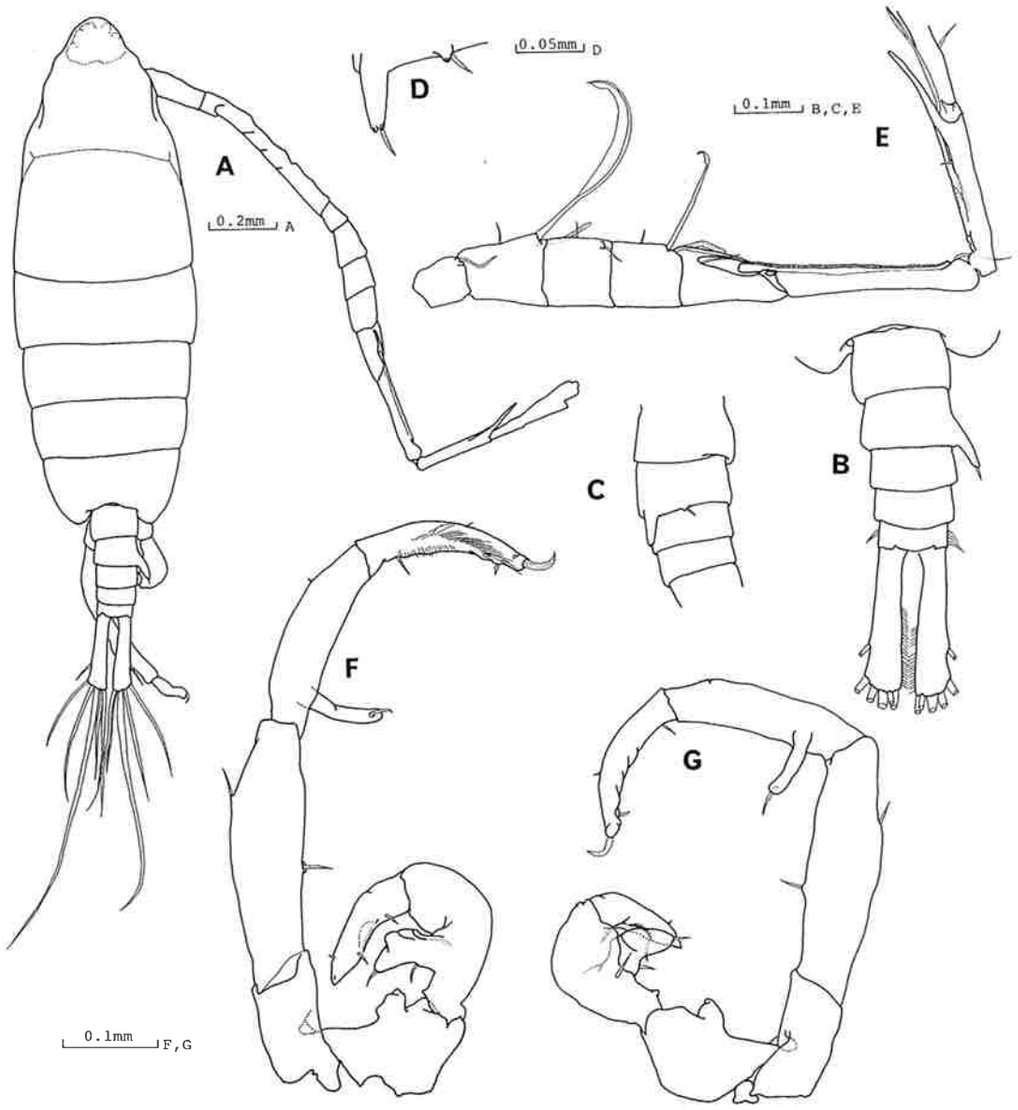

Fig. 6. *Tortanus* (*Atortus*) *digitalis,* new species. Male (paratypes). A, habitus, dorsal view; B, fifth pediger and urosome, dorsal view; C, urosome, ventral view; D, two processes of second urosomal segment; E, segments 13–21 of right antenna 1; F, leg 5, anterior view; G, same, posterior view.

Description of Syntype of Male from Sagami Bay.—Urosomal segment 2 (Fig. 8A) with long slender posterolateral process reaching beyond half length of urosomal segment 3; segment 2 also having small posteroventral process on right side. Leg 5 (Fig. 8B): right leg with large subterminal process directed downward on inner margin of basipod; proximal exopod segment produced inward to form bilobed complex lamellate projection; one lobe elongate, pointing inward, with 1 setule on base and 1 setule on tip; other lobe lower, furnished with longitudinal cleft. Distal exopod segment with distal half spatulate and finely serrate along inner margin. Left leg: proximal exopod segment with inner process located at one-fourth length of segment; distal exopod

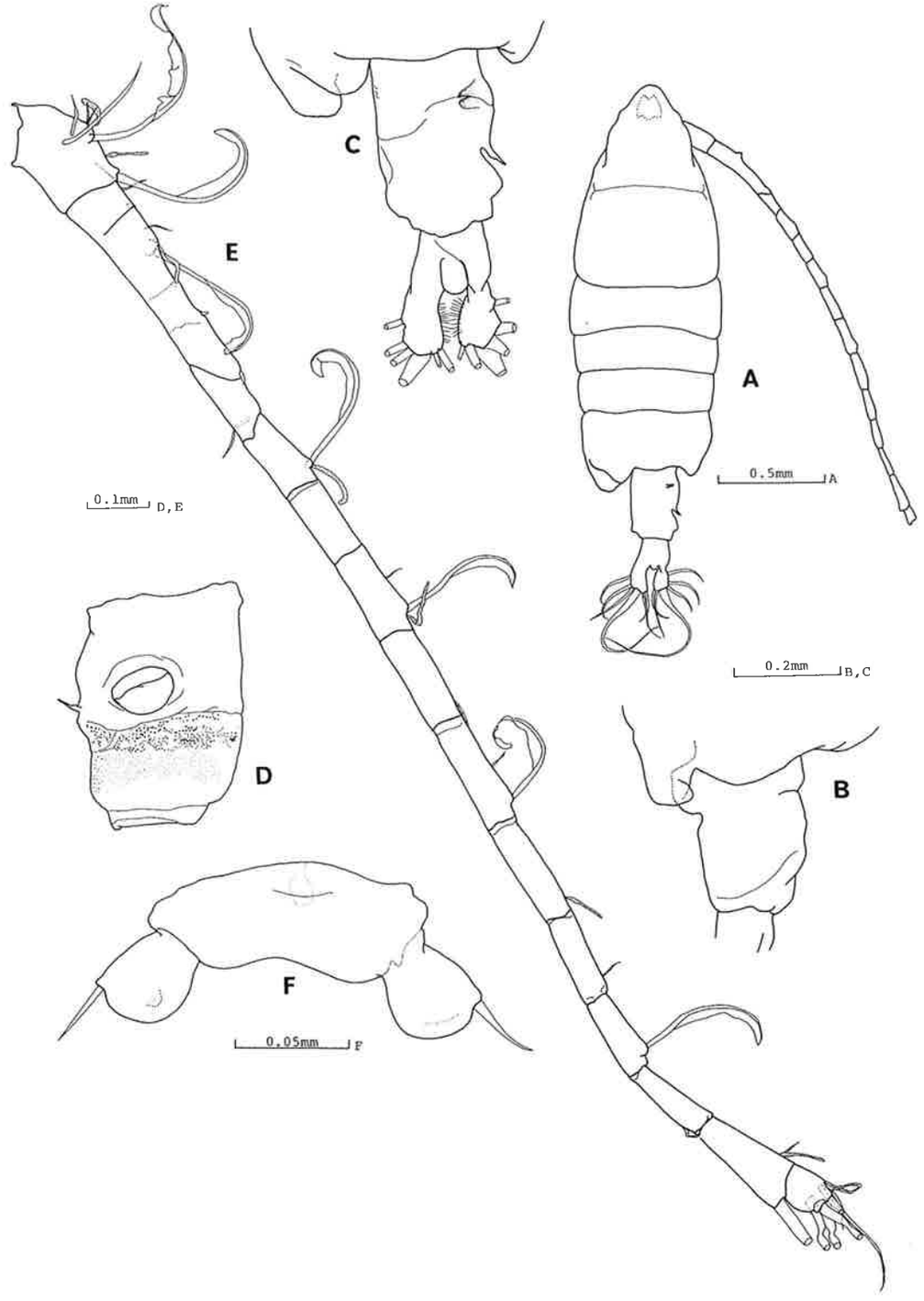

Fig. 7. *Tortanus* (*Atortus*) *rubidus.* Female (specimen from Shijiki Bay). A, habitus, dorsal view; B, fifth pediger and urosome, left lateral view; C, same, dorsal view; D, genital segment, ventral view; E, antenna 1; F, leg 5, anterior view.

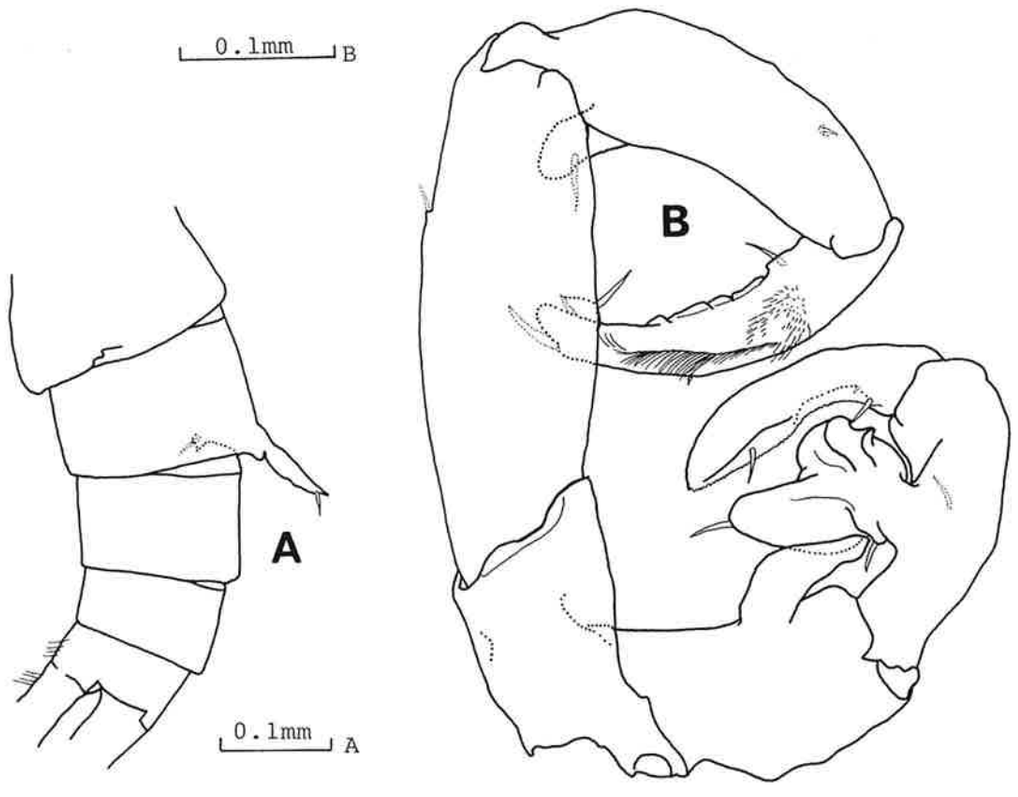

Fig. 8. *Tortanus* (*Atortus*) *rubidus.* Male (syntype). A, urosome, dorsolateral view; B, leg 5, anterior view.

segment with inner margin bearing low lamellate plates.

Description of Males from Shijiki Bay.—Males collected from Shijiki Bay are almost the same as the syntype from Sagami Bay. Body (Fig. 9A) very similar to that of *T. digitalis.* Right lateral process of urosomal segment 2 (Fig. 9B–E) furnished with terminal setule. Right antenna 1 (Fig. 9F) similar to that of *T. digitalis,* but different in shape of segments 17 and 18. Leg 5 (Fig. 9G, H). Inner projection of proximal exopod segment of right leg slightly smaller than that of syntype.

Remarks.—Tanaka (1965) described this species from males only from Sagami Bay, and the female has been unknown until now. The female is for the first time described here and the relationship of this species with the members of the subgenus *Atortus* is discussed below. Reexamination of a syntype of this species revealed that Tanaka's (1965) description of leg 5 of the male is not complete. The large inner projection of the right proximal exopod segment 1 is not as bluntly pointed as originally figured (Tanaka, 1965, see fig. 251e), but broadened distally to form a bilobed fanlike projection. This species is closely related to *T. digitalis* and *T. bowmani* in dimorphic sexual characters, particularly, in right leg 5 of the male.

Distribution (Fig. 10).—This species has been recorded from only three localities, Sagami Bay (Tanaka, 1965) and Shibushi Bay (present study), both on the Pacific coast, and Shijiki Bay facing the Tsushima Strait (Kimoto *et al.,* 1988).

Tortanus (*Atortus*) *longipes* Brodsky, 1950

Material Examined.—Shijiki Bay: 23 ♀♀ (length 2.39 ± 0.04 mm, range 2.31–2.46 mm), 25 ♂♂ (length 2.10 ± 0.04 mm, range 2.03–2.14 mm). Motobu Harbor, Okinawa Island: 1 ♀ (length 2.59 mm), 1 ♂ (length 2.46 mm). Sesoko Island: 1 ♂ (length 2.35 mm).

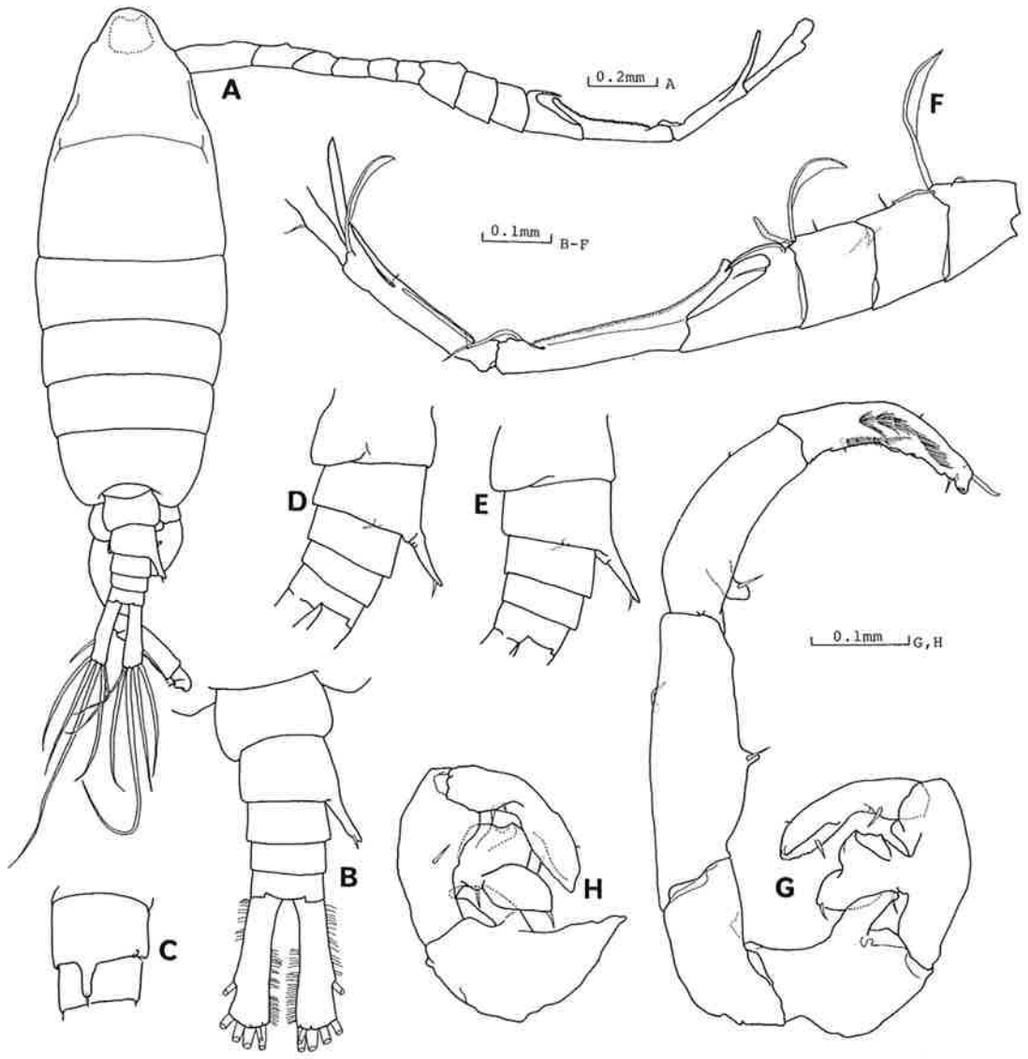

Fig. 9. *Tortanus* (*Atortus*) *rubidus.* Male (specimens from Shijiki Bay). A, habitus, dorsal view; B, urosome, dorsal view; C, second urosomal segment, ventrolateral view; D, E, urosome, dorsolateral view; F, segments 14–21 of right antenna 1; G, leg 5, anterior view; H, right leg 5, posterior view.

Remarks.—Tanaka (1965) reported a female of 2.55 mm and a male of 2.40 mm in body length from Sagami Bay on the Pacific coast, and Brodsky (1950) recorded a male of 2.06 mm long in Poseta Bay in the Sea of Japan. According to the present and previous records, the body lengths of the females and males range from 2.31–2.59 mm and from 2.03–2.46 mm, respectively. This species is most closely related to *T. giesbrechti* collected from Pago Pago Harbor, American Samoa (Jones and Park, 1968).

Distribution (Fig. 10).—This species is distributed in the Sea of Japan (Brodsky, 1950), Sagami Bay (Tanaka, 1965), Tanabe Bay (Ohtsuka *et al.,* 1987b), Shijiki Bay (Kimoto *et al.,* 1988), and the Ryukyu Islands (present study).

Tortanus (*Atortus*) *erabuensis* Ohtsuka, Fukuura and Go, 1987

Material Examined.—Ie Island: 1 ♀ (length 2.42 mm), 1 ♂ (length 2.20 mm). Sesoko Island: 1 ♂ (length 2.10 mm).

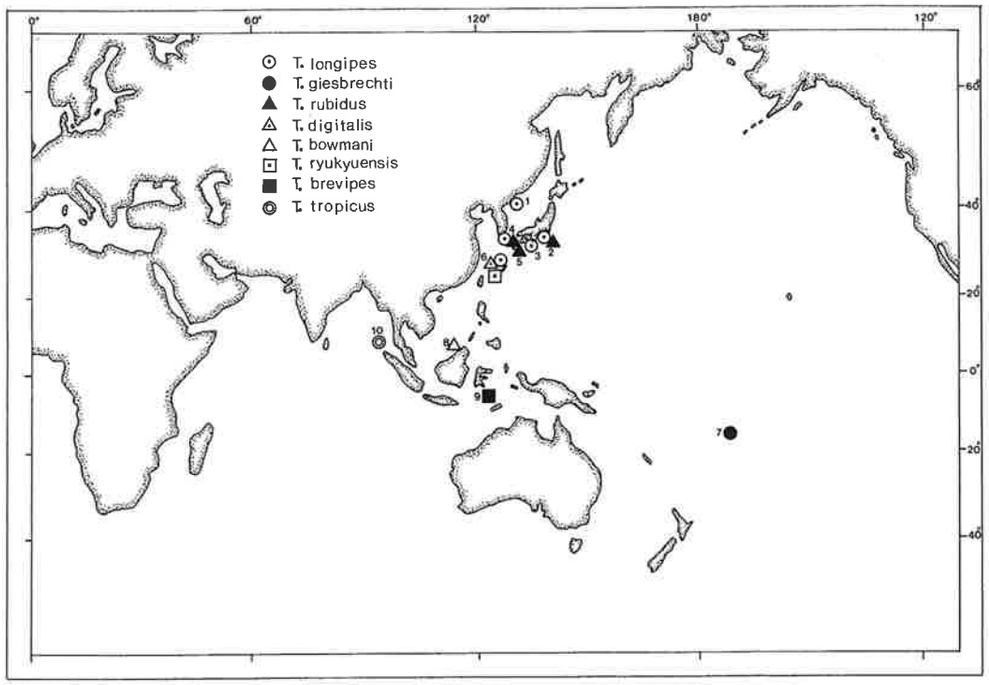

Fig. 10. Distribution of Bowman's (1971) first group of the subgenus *Atortus*. Localities and references are: 1, Poseta Bay (Brodsky, 1950); 2, Sagami Bay (Tanaka, 1965); 3, Tanabe Bay (Ohtsuka *et al.*, 1987b); 4, Shijiki Bay (present study); 5, Shibushi Bay (present study); 6, Ryukyu Islands (present study); 7, Pago Pago Harbor, American Samoa (Jones and Park, 1968); 8, Pulau Tiga, Sabah (Othman, 1987); 9, Saleyer Anchorage (Scott, 1909); 10, Nankauri Harbor, Nicobars (Sewell, 1932).

Remarks.—Ohtsuka *et al.* (1987b) described the holotypic female as 2.44 mm long and an allotypic male as 2.04 mm long, from Kuchinoerabu Island, South Japan.

Distribution (Fig. 11).—The species is recorded from Kuchinoerabu Island (Ohtsuka *et al.*, 1987b) and Ie and Sesoko Islands (present study), southwestern islands of Japan.

Distribution and Relationships in the Subgenus *Atortus*

The distribution patterns of Bowman's (1971) first (Fig. 10) and second groups (Fig. 11) of the subgenus *Atortus* are depicted. The most characteristic feature of their distributions is that each species within the subgenus is endemic to a certain locality in the coastal waters in the Indo-West Pacific region, while the species of the subgenus *Tortanus* are widely distributed on the Indo-Pacific and Atlantic coasts (Ohtsuka, unpublished). In the Indo-Pacific region, *Tortanus* (*Tortanus*) *forcipatus* (Giesbrecht), *T.* (*T.*) *gracilis* (Brady), and *T.* (*T.*) *barbatus* (Brady) are widely distributed (Brady, 1883; Chen and Zhang, 1965; Farran, 1936; Giesbrecht, 1892; Greenwood, 1978; Madhupratap and Haridas, 1986; Sewell, 1932; Steuer, 1926; Tanaka, 1965). *Tortanus* (*T.*) *discaudatus* (Thompson and Scott) has a wide distribution on the North Pacific and the North Atlantic coasts (Brodsky, 1950; Kim, 1985; Steuer, 1926).

Bowman's (1971) first group (see Fig. 10). Six of the eight species belonging to this group (*T. bowmani, T. brevipes, T. digitalis, T. longipes, T. rubidus, T. ryukyuensis*) have been found on the coasts of the islands bordering the westernmost rim of the Pacific Ocean. In addition, *T. giesbrechti* occurs at an oceanic island in the central Pacific, and *T. tropicus* is found in the northeastern Indian Ocean. The species may be classified into two species groups, i.e., the *longipes* group (*T. giesbrechti* and *T. longipes*) and

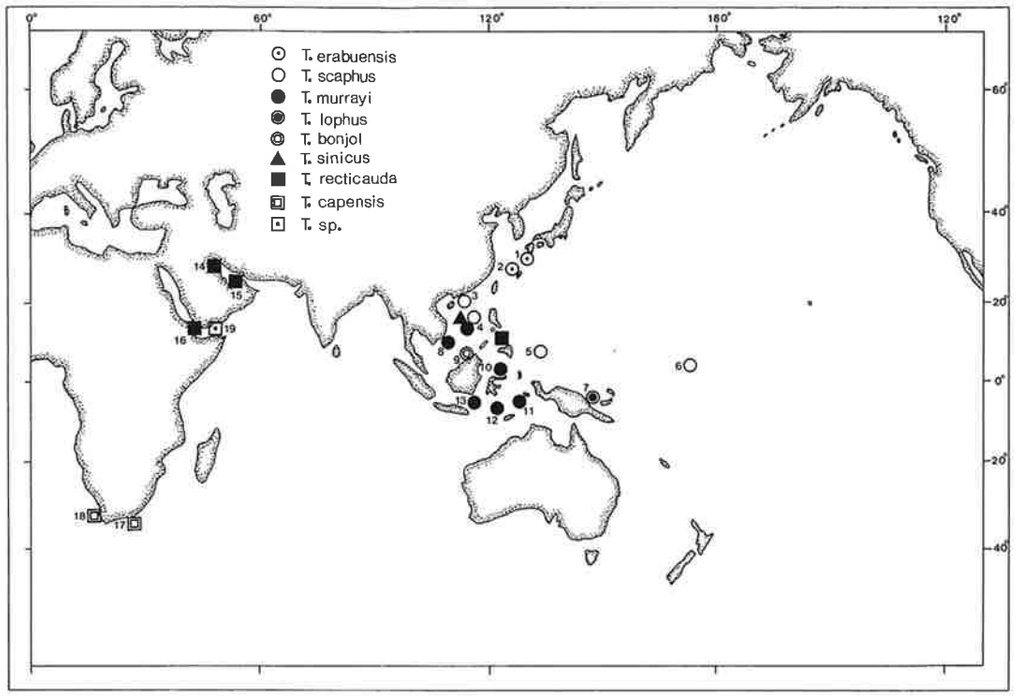

Fig. 11. Distribution of Bowman's (1971) second group of the subgenus *Atortus*. Localities and references are: 1, Kuchinoerabu Island (Ohtsuka *et al.*, 1987a); 2, Ryukyu Islands (present study); 3, Hong Kong (Bowman, 1971); 4, South China Sea, between the Zhongsha Islands and Xisha Islands (Chen, 1983); 5, Malakal Harbor, Koror, Palau Islands (Bowman, 1971); 6, Makin Lagoon, Gilbert Islands (Bowman, 1971); 7, Madang Harbor, New Guinea (Bowman, 1971); 8, Viet-Nam (Bowman, 1971); 9, Pulau Tiga, Sabah (Othman, 1987); 10, Celebes Sea (Scott, 1909); 13, Bay of Kankamaraan, Kangeang (Scott, 1909); 14, Kuwait (Michel and Herring, 1984); 15, Ruweis, United Arab Emirates (Bowman, 1986); 16, Assab (Giesbrecht, 1892); 17, Swartkops estuary, South Africa (Grindley, 1978); 18, Langebaan Lagoon, South Africa (Grindley, 1978); 19, South Yemen (present study).

the *rubidus* group (*T. bowmani, T. digitalis,* and *T. rubidus*). The *longipes* group is morphologically defined as follows: posterior corners of pediger 5 of female more produced on left side; posterior ends of pediger 5 of male asymmetrical, left side slightly longer than right; anterior ridge of segment 18 of right antenna 1 of male strongly retroflexed and extending over distal half of segment 17, and segment 17 with proximal process not reaching distal end of segment; right leg 5 of male with exopodal segment 1 massive and bearing bulbous, medial protuberance with 2 setules, and small exopod segment 2 clawlike and tapering distally; left leg 5 of male with sinuate inner margin of basipod 2 bearing large acute proximal process and 3 or 4 small blunt or pointed processes. The two species belonging to this group, *T. longipes* and *T. giesbrechti,* however, have been recorded far from each other. The speciation process of these two isolated species could not easily be explained, but the occurrence of species related to these two species in the intermediate regions, e.g., the Philippines and Indonesian Islands, would make the explanation on the speciation process easier (Nishimura, personal communication). The *rubidus* group possesses the following characters: posterior corners of prosome of female asymmetrical, left side bearing irregularly pointed ventrolateral process and right side with rounded or pointed lobe; leg 5 of female reduced and 2-segmented, terminal segment lamellate with outer plumose seta; posterior prosomal ends of male symmetrical; proximal process of segment 17 of right antenna 1 of male slender and extending over half of segment; right leg 5 of male with basipod bearing

inner subterminal process, exopod segment 1 having broad inner medial projection with 2 short setae along posterior half, exopod segment 2 about as long as preceding segment; left leg 5 of male with exopodal segment 1 bearing large cylindrical inner process proximally. Females of *T. longipes* in the *longipes* group and all species in the *rubidus* species group have a reduced leg 5 with the terminal segment lamellate and bearing an outer plumose seta distally. This is thought to be an example of parallelism. The *rubidus* group is continuously distributed in the westernmost rim of the Pacific Ocean from southern Japan to Borneo and not found in any other region. The relationships of three other species (*T. brevipes, T. ryukyuensis,* and *T. tropicus*) with the above described two species groups are not clear because of the lack of descriptions of both sexes and/or the absence of information on their occurrences except for the type localities. The members of Bowman's (1971) first group have not been found on the western coasts of the Indian Ocean where the second group occurs (see Fig. 11).

Bowman's (1971) second group. Five species (*T. bonjol, T. erabuensis, T. lophus, T. murrayi, T. scaphus*) found in the westernmost rim of the Pacific Ocean make a distinctive species group, the *murrayi* group. Definition of the species group is as follows: caudal rami of female considerably asymmetrical; leg 5 of female with terminal segment bearing 3 prongs at tip; posterior prosomal ends of male symmetrical; right leg 5 of male with exopod segment 1 broad and having posterior inner margin bearing 1 or more projections to form compact chela together with exopod segment 2; exopod segment 2 bearing medial or subterminal inner projection. These species are allopatric or partly sympatric in the westernmost Pacific: *T. erabuensis* occurs along the Nansei Islands; *T. murrayi* is distributed in the eastern seas of the Indo-Malayan region, whereas *T. scaphus* has a wide distribution on the western Pacific coast; *T. bonjol* and *T. lophus* are recorded only from their type localities in the coastal waters of Borneo and New Guinea, respectively. The distributional patterns of *T. erabuensis, T. murrayi,* and *T. scaphus* are quite similar to those of three species of the *Pontella alata* species group, *P. rostraticauda, P. alata,* and *P. surrecta,* along the westernmost rim of the Pacific Ocean (see Ohtsuka *et al.,* 1987a, fig. 10). It may be that these two neritic species groups had experienced the same evolutionary process in speciation as hypothesized by Fleminger (1986) for the pontellid copepod speciation in and around "Wallacea." In addition, three species, *T. capensis, T. recticauda,* and *Tortanus* sp., collectively called the *recticauda* group, are found to be distributed in the West Indian Ocean. Four males of an unidentified species of *Tortanus* collected from the coast of South Yemen (13°45′N, 46°35′E) are very similar to *T. capensis* in the structure of the right antenna 1 and leg 5 (Ueda, personal communication). However, this species is undoubtedly an undescribed species. The *recticauda* group is characterized as follows: caudal rami of female incompletely fused with anal segment; leg 5 of female 3-segmented, with terminal segment pointed distally and bearing small inner prong; right leg 5 of male: inner medial or distal margin of basipod produced; exopod segment 1 with inner medial or terminal large projection; exopod segment 2 elongate, longer than preceding segment. No information is yet available on the occurrence of this species group on the middle East African coasts. Wilson (1950) recorded a *T. recticauda* female from Iloilo Straits, Philippines, far from the type locality, the Red Sea, and stated that the specimen was deposited in the United States National Museum. However, there is no specimen in the alcoholic collection or slide collection in the museum (T. E. Bowman, personal communication). Considering the restricted distribution patterns of other members of *Atortus,* we doubt the validity of Wilson's (1950) identification. *Tortanus sinicus* from the South China Sea has less obvious relationship with other members of Bowman's (1971) second group, although the species is partly similar in shape to the other species of the group and its distribution overlaps those of *T. murrayi* and *T. scaphus.*

Each of Bowman's (1971) two groups (=the *murrayi* group and the *tropicus* group sensu Othman, 1987) contains several species groups and corresponds to the species complex defined by Fleminger *et al.* (1982).

Table 2. Density (number m^{-3}) of copepodids of *Tortanus, Acartia,* and other genera just above the bottom at different stations in the inner part of Shijiki Bay. U = 20–40 cm above the bottom; L = 0–20 cm above the bottom.

Dates local time	Sampling stations	Layers	*T. rubidus* ♀	*T. rubidus* ♂	*T. longipes* ♀	*T. longipes* ♂	*Tortanus* Immature	*Tortanus* Total	*Acartia*	Others
10 July 1984 0942	Rocky bottom with small brown algae (6 m deep)	U	0	4	2	5	1	12	4.1×10^3	20.2×10^3
		L	1	7	1	7	10	26	43.3×10^3	35.3×10^3
11 July 1984 1551	Sandy bottom near shore (2 m deep)	U	0	3	9	6	9	27	0.5×10^3	2.2×10^3
		L	0	18	26	39	191	274	0.9×10^3	6.9×10^3
12 July 1984 1355	Inside eelgrass bed (6 m deep)	U	0	1	1	0	1	3	1.5×10^3	2.5×10^3
		L	1	15	10	10	32	68	37.0×10^3	4.5×10^3
13 July 1984 0855	Sandy bottom near shore (2 m deep)	U	0	1	0	2	4	7	1.2×10^3	14.7×10^3
		L	0	3	8	12	9	32	0.6×10^3	12.9×10^3

The first and second groups may be referred to as the *brevipes* complex and the *recticauda* complex, respectively.

Swarming Behavior of the Subgenus *Atortus*

Swarm formation has commonly been observed in neritic copepods such as *Acartia* and *Oithona* with SCUBA (Hamner and Carleton, 1979; Kimoto *et al.,* 1988; Tanaka *et al.,* 1987; Ueda *et al.,* 1983). However, little is known about the swarms of *Atortus.* Kimoto *et al.* (1988) reported a small cylindrical swarm of copepodids of both *Tortanus* (*Atortus*) *rubidus* and *T.* (*A.*) *longipes* at a depth of 2 m in a small inlet. *Tortanus* (*A.*) *erabuensis* was also observed making an oval school consisting mainly of stage V copepodids near the bottom at a depth of 2 m in Kuchinoerabu Island, Kyushu, on 3 October 1988 (Ohtsuka, unpublished). On the contrary, the subgenus *Tortanus* has never been reported to form swarms.

Table 2 shows the density of copepodids of *T.* (*A.*) *longipes, T.* (*A.*) *rubidus,* and other copepods near the bottom in Shijiki Bay during 10–13 July 1984. These copepods were much more abundant in the 0–20 cm layer than in the 20–40 cm layer above the bottom sediments, except for a sample collected on 13 July 1984. Copepodids of *Atortus* were apparently concentrated in the 0–20-cm layer and their density was about twice to 20 times as many as in the 20–40 cm layer. However, the density of *Atortus* was much lower than that of *Acartia* and other copepods. *Tortanus erabuensis, T. digitalis,* and *T. ryukyuensis* were also collected from near the bottom in shallow waters (Ohtsuka *et al.,* 1987a; present study). These indicate that *Atortus* copepodids are concentrated within a thin layer just above the sea bottom and form small swarms during the daytime. According to Madhupratap and Haridus (1986), there are no recent records of occurrences of *T. brevipes, T. tropicus,* and *T. murrayi* from the northern Indian Ocean. This might be due to the fact that the copepods live near the bottom during the daytime and are difficult to collect by conventional plankton tows.

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Literature Cited

Bowman, T. E. 1971. *Tortanus scaphus* and *Tortanus lophus,* new Pacific planktonic copepods, with notes on *Tortanus murrayi* (Calanoida, Tortanidae).—Pacific Science 25: 521–528.

———. 1986. *Tortanus recticauda*: extension of range to Arabian Gulf (Copepoda, Calanoida, Tortanidae).—Crustaceana 50: 239–242.

Brady, G. S. 1883. Report on the Copepoda collected by H.M.S. Challenger during the years 1873–76.—Report on the Scientific Results of H.M.S. Challenger, Zoology 8: 1–142.

Brodsky, K. A. 1950. Calanoida of polar and far-

eastern seas of the U.S.S.R.—Opredeliteli po Fauna S.S.S.R. 35: 1–442. [In Russian.]
Chen, Q.-C. 1983. The pelagic copepods of the South China Sea III.—Contributions on Marine Biological Research of the South China Sea 1: 133–138. [In Chinese with English abstract.]
———, and S.-Z. Zhang. 1965. The planktonic copepods of the Yellow Sea and the East China Sea. I. Calanoida.—Studia Marina Sinica 7: 20–131. [In Chinese with English abstract.]
Farran, G. P. 1936. Copepoda.—Great Barrier Reef Expedition 1928–29, Scientific Reports 5: 73–142.
Fleminger, A. 1986. The Pleistocene equatorial barrier between the Indian and Pacific Oceans and a likely cause for Wallace's Line.—*In:* A. C. Pierrot-Bults, S. van der Spoel, B. J. Zahurance, and R. K. Johnson, Pelagic biogeography. Unesco technical papers in marine science 49: 84–97.
———, B. H. R. Othman, and J. G. Greenwood. 1982. The *Labidocera pectinata* group: an Indo-West Pacific lineage of planktonic copepods with descriptions of two new species.—Journal of Plankton Research 4: 245–270.
Giesbrecht, W. 1892. Systematik und Faunistik der pelagishen Copepoden des Golfes von Neapel.—Fauna und Flora des Golfes von Neapel und der angrenzenden Meeresabschnitte 19: 1–831.
González, J. G., and T. E. Bowman. 1965. Planktonic copepods from Bahia Fosforescente, Puerto Rico, and adjacent waters.—Proceedings of the United States National Museum 117: 241–303.
Greenwood, J. G. 1978. Calanoid copepods of Moreton Bay (Queensland) III. Families Temoridae to Tortanidae, excluding Pontellidae.—Proceedings of the Royal Society of Queensland 89: 1–21.
Grindley, J. R. 1978. A new species of *Tortanus* (Crustacea, Copepoda) from South Africa.—Annals of the South African Museum 74: 219–228.
Hamner, W. M., and J. H. Carleton. 1979. Copepod swarms: attributes and role in coral reef ecosystems.—Limnology and Oceanography 24: 1–14.
Jones, E. C., and T.-S. Park. 1968. A new species of *Tortanus* (Calanoida) from Pago Pago Harbor, American Samoa.—Crustaceana, Supplement 1, Studies on Copepoda: 152–158.
Kim, D.-Y. 1985. Taxonomical study on calanoid copepod (Crustacea: Copepoda) in Korean waters.—D.Sc. thesis. Hanyang University, Seoul. Pp. 1–187.
Kimoto, K., J. Nakashima, and Y. Morioka. 1988. Direct observations of copepod swarm in a small inlet of Kyushu, Japan.—Bulletin of the Seikai Regional Fisheries Research Laboratory 66: 41–58.
Madhupratap, M., and P. Haridas. 1986. Epipelagic calanoid copepods of the northern Indian Ocean.—Oceanologica Acta 9: 105–117.
Michel, H. B., and D. C. Herring. 1984. Diversity and abundance of Copepoda in the northwestern Arabian Gulf.—Crustaceana, Supplement 7, Studies on Copepoda II: 326–335.
Ohtsuka, S., A. Fleminger, and T. Onbé. 1987a. A new species of *Pontella* (Copepoda: Calanoida) from the Inland Sea of Japan with notes on its feeding habits and related species.—Journal of Crustacean Biology 7: 554–571.
———, Y. Fukuura, and A. Go. 1987b. Description of a new species of *Tortanus* (Copepoda: Calanoida) from Kuchinoerabu Island, Kyushu, with notes on its possible feeding mechanism and in-situ feeding habits.—Bulletin of Plankton Society of Japan 34: 53–63.
Othman, B. H. R. 1987. Two new species of *Tortanus* (Crustacea, Copepoda) from Sabah, Malaysia.—Malayan Nature Journal 41: 61–73.
Scott, A. 1909. The Copepoda of the Siboga Expedition 1. Free swimming, littoral, and semi-parasitic Copepoda.—Siboga Expeditie, Monograph 29a: 1–323.
Sewell, R. B. S. 1932. The Copepoda of Indian Seas. Calanoida.—Memoirs of the Indian Museum 10: 223–407.
Steuer, A. 1926. Revision der copepoden Gattung *Tortanus* Giesbr.—Bollettino della Società Adriatica di Scienze Naturali Trieste 29: 49–69.
Tanaka, M., H. Ueda, and M. Azeta. 1987. Near-bottom copepod aggregations around the nursery ground of the juvenile red sea bream in Shijiki Bay.—Nippon Suisan Gakkaisi 59: 1537–1544.
Tanaka, O. 1965. The pelagic copepods of the Izu Region, Middle Japan. Systematic Account XIII. Parapontellidae, Acartiidae and Tortanidae.—Publications of the Seto Marine Biological Laboratory 12: 379–408.
Ueda, H., A. Kuwahara, M. Tanaka, and M. Azeta. 1983. Underwater observations on copepod swarms in temperate and subtropical waters.—Marine Ecology-Progress Series 11: 165–171.
Wilson, C. B. 1950. Copepods gathered by the United States Fisheries Steamer "Albatross" from 1887 to 1909, chiefly in the Pacific Ocean.—Bulletin of the United States National Museum 100: 141–441.

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