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A new species of the calanoid copepod genus *Centropages* (Crustacea) collected from Shimizu Port, Middle Japan: Introduced or not?

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Abstract: A new species of the planktonic calanoid copepod *Centropages* is described from Shimizu Port, Middle Japan. The new species is assigned to the *alcocki* group that is distributed in the tropical/subtropical Indo-West Pacific regions. The sporadic occurrence of the new species alludes to the possibility that the new species was introduced to Japan via ballast water.

Key words: *Centropages maigo*, alien species, Calanoida, ballast water, Shimizu Port

Introduction

Alien marine benthic species are an increasingly serious problem all over the world and are now being joined by planktonic species. On the Pacific coast of the U.S.A. and Chile, many planktonic copepods have been introduced from East Asia via ballast water, some of which have well-established populations (e.g., Orsi & Ohtsuka 1999; Bollens et al. 2002, Ohtsuka et al. 2004). An alien copepod *Pseudodiaptomus marinus* Sato, 1913 introduced from East Asia to California, U.S.A. is thought to be out-competing a native congener *P. euryhyalinus* Johnson, 1939 (Fleminger & Kramer 1988). Some alien pelagic copepods have become one of the major food items for benthic crustaceans (Bollens et al. 2002). Alien copepods appear to be disrupting native ecosystems. Marine alien invasions are increasing, due to intensification of economic activities via ships (Gollasch et al. 2000). In contrast to the American Pacific coasts, no alien phyto- and zooplankters have been recorded from Japanese waters (Ohtsuka et al. 2004).

During our survey on alien plankton around Japan, a new species of planktonic calanoid copepod of the genus *Centropages* was found from Shimizu Port, Shizuoka Prefecture on the Pacific coast of Middle Japan. The genus is widely distributed in brackish to oceanic waters, and some coastal species are very abundant and play important roles as food for fish (Brodsky 1950, Chen & Zhang 1965). In Japanese waters the following ten species of the genus have hitherto been recorded: *C. abdominalis* Sato, 1913; *C. bradyi* Wheeler, 1899; *C. calaninus* (Dana, 1849); *C. elongatus* Giesbrecht, 1896; *C. furcatus* (Dana, 1849); *C. gracilis* (Dana, 1849); *C. longicornis* Mori, 1932; *C. orsinii* Giesbrecht, 1889; *C. tenuiremis* Thompson & Scott, 1903; *C. violaceus* (Claus, 1863) (cf. Mori 1937, Tanaka 1963). The new species has hitherto been recorded only from the type locality. Its sporadic occurrence in Japanese waters suggests three possibilities. (1) It is a native species that is difficult to collect due either to its low numbers, a restricted distribution near the surface or bottom, or a limited occurrence in time due to patterns of diapause egg production and hatching; (2) it has been introduced in a temporary extension of the Kuroshio Current from some tropical/subtropical area where the copepod fauna is not well-known; or (3) it is an alien species introduced to Japan. These possibilities are assessed on the basis of morphological and zoogeographical relationships between the new species and its close relative species, and of international trade statistics at the Shimizu Port.

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Materials and Methods

This new species was found in a plankton sample collected from a station at the entrance of Shimizu Port in Suruga Bay, the Pacific coast of Middle Japan (35°01′16″N, 138°32′02″E; depth 38 m), on 1 November 1979, using a NORPAC plankton net (mesh size 0.33 mm) hauled vertically from 30 m deep to the surface. Samples were immediately fixed and preserved in 10% formalin-sea water solution. Sorted copepods were examined with a differential interference microscope (Nikon Optiphoto). Drawings were made with the aid of a camera lucida. Terminology follows Huys & Boxshall (1991).

Types are deposited at the Kita-Kyushu Natural History and Human History Museum, Fukuoka, Japan (KMNH IvR).

Systematics

Family Centropagidae Giesbrecht, 1892
Genus *Centropages* Krøyer, 1849
***Centropages maigo* n. sp.**

(Figs 1–3)

Material examined. 18♀♀ and 12♂♂, Shimizu Port, Shizuoka Prefecture, Japan (35°01′16″N, 138°32′02″E).

Types. Holotype: 1♀, partly dissected and mounted on glass slides (KMNH IvR 500, 108). Paratypes: 2♂♂, partly dissected and mounted on glass slides (KMNH IvR 500, 109; 500, 110); 9♀♀ and 6♂♂, whole specimens (KMNH 500, 111–500, 125).

Body length. Female: 1.15–1.24 mm (mean±standard deviation=1.207±0.024 mm, n=10); male: 1.04–1.12 mm (1.096±0.026 mm, n=8)

Description. Female (holotype, paratypes). Body (Fig. 1A, B) with plump prosome, widest at posterior end of cephalosome; cephalosome separate from pediger 1, bearing small knob at posterodorsal median end; prosome about 2.5 times as long as urosome. Rostrum (Fig. 1C) developed, with pair of long filaments. Pedigers 4 and 5 separate; pediger 5 (Fig. 1D) slightly asymmetrically produced posteriorly into acute process; right process longer than left.

Urosome (Fig. 1D) 3-segmented. Genital compound somite (Fig. 1D, E) strongly asymmetrical, with middle and posterior lateral swellings on right and left sides, respectively; small anteroventral process terminating roundly; posteroventral extension produced posteriorly beyond posterior margin of compound somite; genital operculum located half way along ventral surface, off center to left. Second urosomite (Fig. 1D) swollen anterolaterally on right side; anal somite asymmetrical, slightly produced posterolaterally on right side; caudal rami (Fig. 1A, D) slightly asymmetrical; caudal seta I rudimentary; right caudal seta II spinulose along outer posterior half, while left plumose along both sides; seta V longest.

Antennule (Fig. 1F, G) 22-segmented, reaching beyond prosomal end; armature and fusion pattern as follows: I (1) =2+ae, II–VI (2)=6+3ae, VII (3)=2+ae, VIII (4)=2+ae, IX (5)=2+ae, X (6)=2 (1 spiniform)+ae, XI (7) =2+ae, XII (8)=2+ae, XIII (9)=2+ae, XIV (10)=2 (1 spiniform)+ae, XV (11)=2+ae, XVI (12)=2+ae, XVII (13)=2+ae, XVIII (14)=2+ae, XIX (15)=2+ae, XX (16) =2+ae, XXI (17)=2+ae, XXII (18)=1, XXIII (19)=1, XXIV (20)=1+1, XXV (21)=1+1+ae, XXVI–XXVIII (22)=6 (1 rudimentary)+ae. Antenna (Fig. 2A) with short coxa bearing stout, plumose seta inserted posteriorly; basis with 2 subequal terminal setae; exopod incompletely 7-segmented, setal formula 1, 3, 1, 1, 1, 1, 3+1; endopod 2-segmented, proximal segment with 2 setae of unequal length at posterior one-third, distal segment with 9 and 7 setae on subterminal and terminal lobes, respectively. Mandible (Figs. 1H, 2B) with 8 teeth and 1 spinulose seta on cutting edge; basis with 4 setae along inner margin midway; exopod indistinctly 5-segmented, setal formula 1, 1, 1, 1, 2; endopod 2-segmented, proximal segment 4 setae at distal corner, distal segment with 9 setae and row of spinules. Maxillule (Fig. 2C) well developed; praecoxal sclerite with 16 elements; coxal epipodite and endite bearing 9 and 3 setae, respectively; basal exite with rudimentary seta; basis incompletely fused to endopod, first and second basal endites having 4 and 5 setae, respectively; proximal endopodal segments 1 and 2 incorporated into basis, represented by 6 setae along inner margin, distal endopodal segment free from compound segment, with 3 setae; exopod lobate, 9 outer setae. Maxilla (Fig. 2D) well developed; first praecoxal endite with 1 rudimentary element and 5 setae, one of which being directed inward; second praecoxal to basal endites each with 3 setae; setal formula of endopod 3 (2 rudimentary), 2 (1 rudimentary), 2, 2. Maxilliped (Fig. 2E) with 4 syncoxal lobes, on which 1, 2, 3 and 4 setae (1 rudimentary) present; basis longer than syncoxa, with 3 inner setae and spinular row along proximal two-thirds of inner; first endopodal segment almost completely incorporated into basis, with 2 unequal setae; second to sixth endopodal segments with 2, 3, 2, 2+1, and 4 setae, respectively.

Seta and spine formula of legs 1 to 5 shown in Table 1. Leg 1 (Fig. 2F) with basis bearing 1 outer, rudimentary and 1 inner, spinulose setae. Legs 2 to 4 (Fig. 2G–I) similar to one another except for number of inner setae on third endopodal segment. Leg 5 (Fig. 2J) with unarmed coxa; basis with short outer seta; first exopodal segment swollen midway along inner margin; second exopodal segment with strong, serrate process at inner distal corner; first endopodal segment expanded distolaterally into rounded lobe.

Male (paratypes). Body (Fig. 3A) as in female, but more slender; posterior prosome slightly asymmetrical, with left process longer than right. Urosome (Fig. 2B) almost symmetrical except for genital somite with gonopore on left side (in dorsal view).

Right antennule (Fig. 3C) geniculate between segments ancestral segment XX and XXI, 22-segmented; armature and fusion pattern as follows: I (1)=2+ae, II–IV (2)=3+ae, V (3)=1+ae, VI (4)=2+ae, VII (5)=2+ae, VIII (6)=1 +ae, IX (7)=2+ae, X (8)=2 (1 rudimentary)+ae, XI (9)= 2+ae, XII (10)=2 (1 spiniform)+ae, XIII (11)=2 (1 spiniform)+ae, XIV (12)=2 (1 spiniform)+ae, XV (13)=2+ae, XVI (14)=2+ae, XVII (15)=2+ae, XVIII (16)=2+ae,

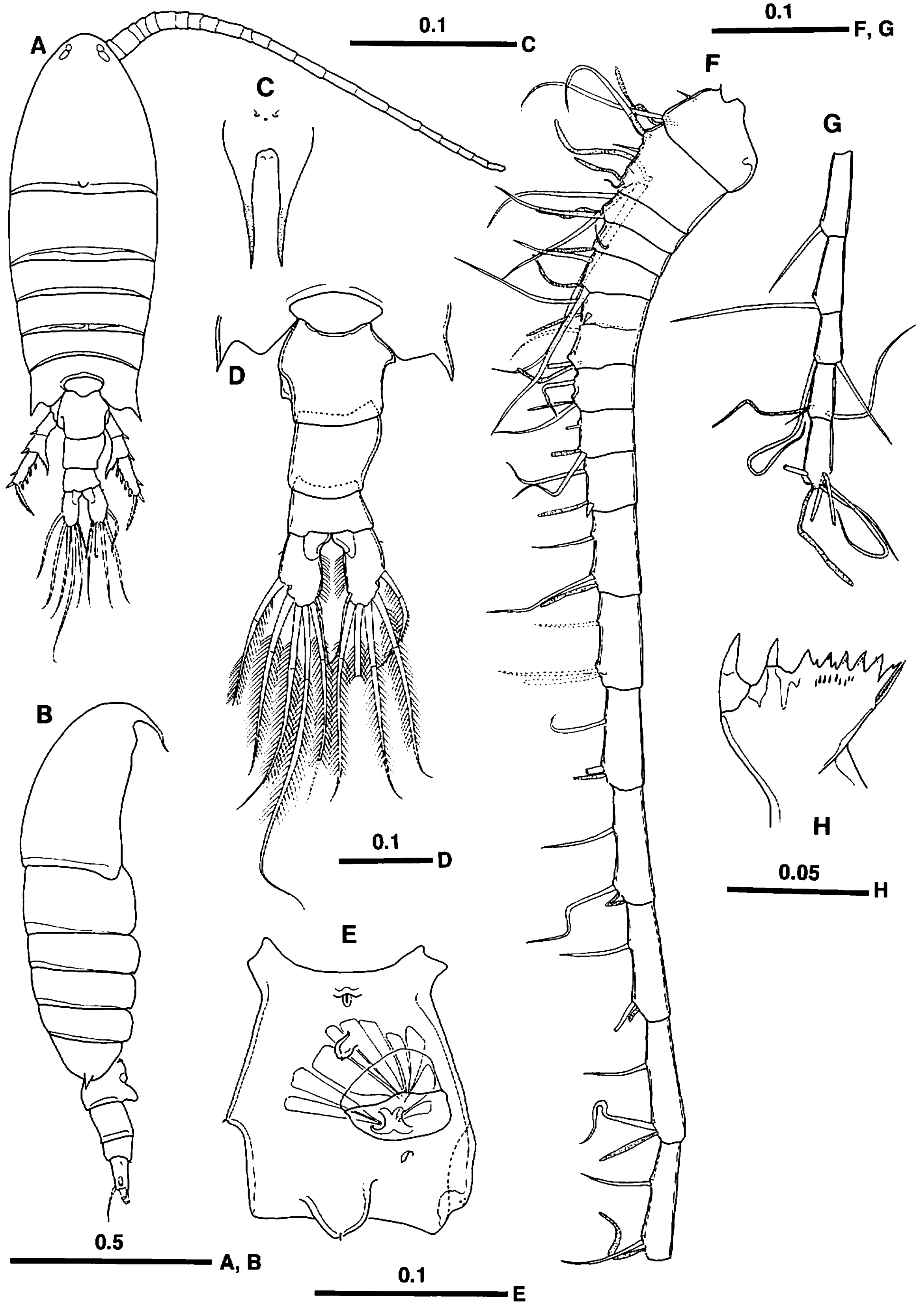

Fig. 1. *Centropages maigo* n. sp., female (holotype). A. Habitus, dorsal view; B. Habitus, lateral view; C. Rostrum, anterior view; D. Urosome, dorsal view; E. Genital compound somite, ventral view; F. Antennule, first (I) to 17th (XXI) segments; G. Antennule, 18th (XXII) to 22nd (XXVI–XXVIII) segments; H. Mandibular gnathobase. Scales in mm.

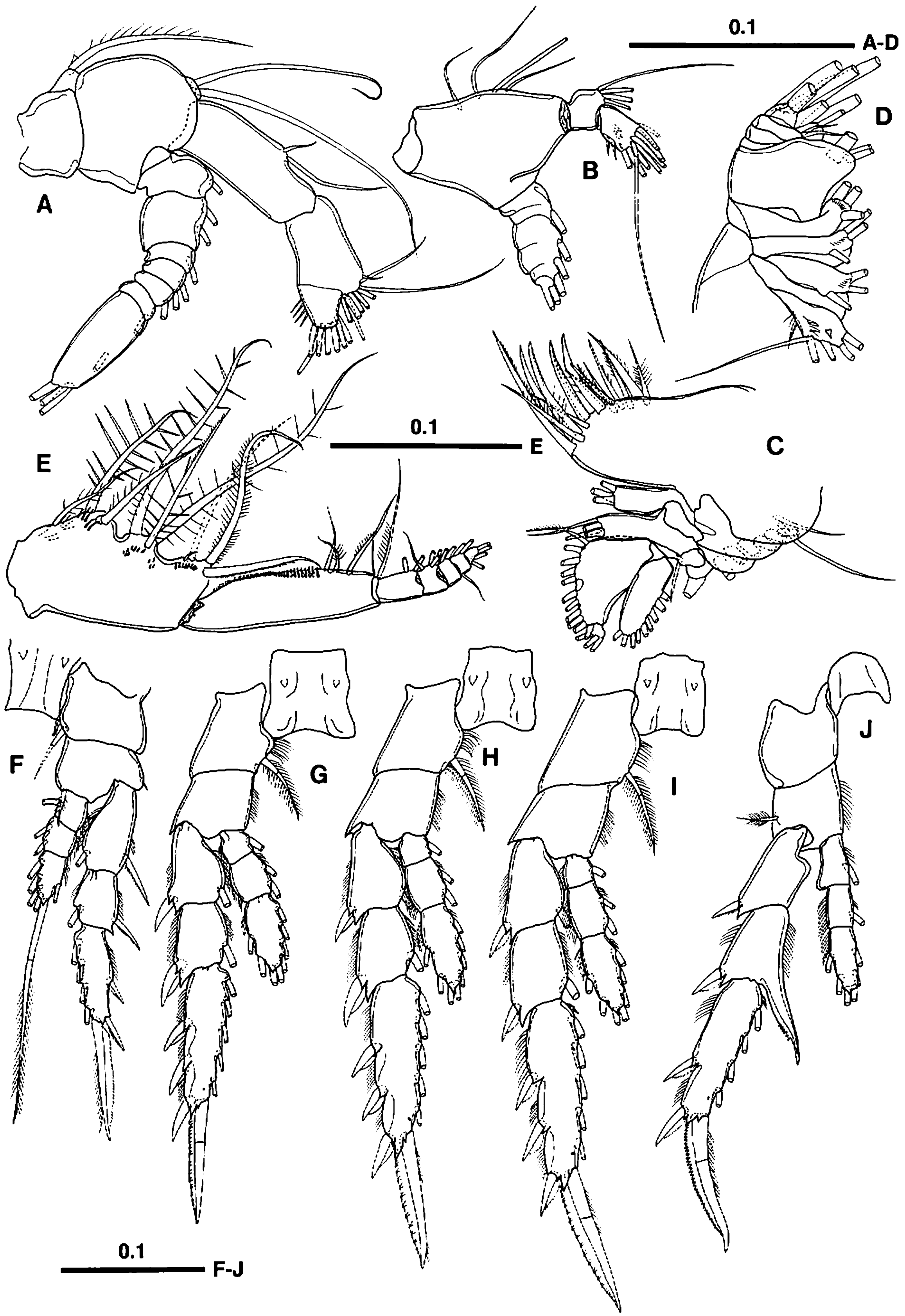

Fig. 2. *Centropages maigo* n. sp., female (holotype). A. Antenna; B. Mandibular palp; C. Maxillule; D. Maxilla; E. Maxilliped; F. Leg 1, anterior view; G. Leg 2, anterior view; H. Leg 3, anterior view; I. Leg 4, anterior view; J. Leg 5, anterior view. Scales in mm.

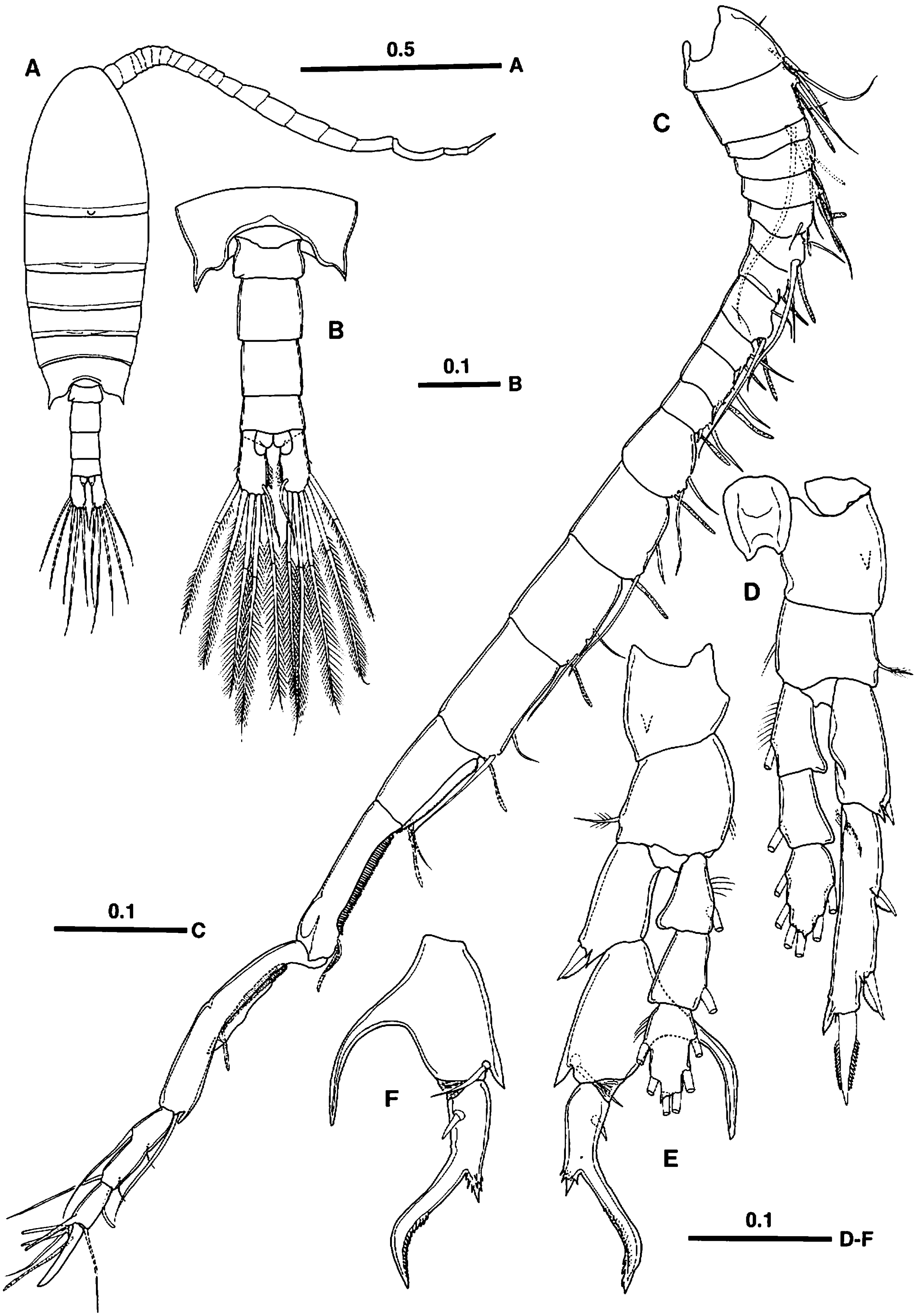

Fig. 3. *Centropages maigo* n. sp., male (paratype). A. Habitus, dorsal view; B. Urosome, anterior view; C. Right antennule; D. Left leg 5, anterior view; E. Right leg 5, anterior view; F. Second and third exopodal segments of right leg 5, posterior view. Scales in mm.

Table 1. Seta and spine formula of leg 1–5 of female *Centropages maigo* n. sp.

	Coxa	Basis	Exopod			Endopod		
			1	2	3	1	2	3
Leg 1	0–1	1–1	I–1;	I–1;	II, I, 4	0–1;	0–2;	1, 2, 2
Leg 2	0–1	0–0	I–1;	I–1;	III, I, 5	0–1;	0–2;	2, 2, 4
Leg 3	0–1	0–0	I–1;	I–1;	III, I, 5	0–1;	0–2;	2, 2, 4
Leg 4	0–1	0–0	I–1;	I–1;	III, I, 5	0–1;	0–2;	2, 2, 3
Leg 5	0–0	1–0	I–1;	I–1;	II, I, 4	0–1;	0–1;	2, 2, 2

XIX (17)=1+ae+process, XX (18)=1+ae+process, XXI–XXIII (19)=2 (1 rudimentary)+ae+3 processes, XXIV–XXV (20)=2+2+ae, XVI (21)=1+1, XXVII–XXVIII (22)=3+ae+process.

Leg 5 (Fig. 3D–F) with intercoxal sclerite narrower than those of legs 2 to 4; coxae with acute prominence on posterior surface; basis with short outer seta. Right leg 5 (Fig. 3E, F) with both rami 3-segmented; second exopod drawn into smoothly curved inner process without ornamentation; third exopodal segment with spinulose process at outer midlength and serration along outer margin of posterior one-third of segment; first and second endopodal segments produced distolaterally. Left leg 5 (Fig. 3D) with 2-segmented exopod and 3-segmented endopod; exopod slender, second segment with acute process at inner distal corner; endopod similar to that on right side.

Remarks. The new species is similar to *Centropages alcocki* Sewell, 1912 from Cochin and Rangoon River, *C. sinensis* Chen & Zhang, 1965 from the South China Sea and Indonesian, and *C. karachiensis* Haq & Fazal-Ur-Rehman, 1973 from the coast of Karachi, in the structures of the prosomal corners and urosomes of both sexes and of the male fifth legs (cf. Sewell 1912, Chen & Zhang 1965, Wellershaus 1970, Mulyadi 2004). However, it is readily distinguished from these three species in that: (1) the posterior prosome of both sexes is more acutely produced posteriorly; (2) the female genital compound somite is very asymmetrical, with a ventroposterior swelling; (3) the second urosomite of the female is asymmetrical, with an anterolateral expansion on the right side; (4) the outer distal spine on the third exopodal segment of right leg 4 (found only in *C. sinensis*) is not modified; (5) terminal spines on the third exopodal segments of female leg 5 are as long as the segment; (6) the right endopod of the male fifth leg does not reach beyond the distal margin of the second exopodal segment; and (7) the terminal spine on the third exopodal segment of the male left leg 5 is about three times as long as the inner distal spine/process.

Etymology. The specific name of the new species (Japanese noun, meaning lost child) alludes to the possibility that it was introduced via ballast water from somewhere in the tropical/subtropical regions of the Indo-West Pacific region to Japan.

Discussion

Vervoort (1964) provisionally divided species of the genus *Centropages* into five species groups without any definition. Ohtsuka et al. (2003) pointed out the heterogeneity of some groups referred to by Vervoort (1964) and the necessity of a revision of his species groups. Ohtsuka et al. (2003) newly recognized one distinct species group, the *trispinosus* group to accommodate two species occurring in the Indo-West Pacific tropical region. Systematic relationships of *Centropages alcocki*, *C. sinensis*, *C. karachiensis* and *C. maigo* have never been discussed because of their discovery since the work of Vervoort (1964). These four species are here grouped as the *alcocki* group, which shares the following features: (1) female with relatively compact prosome; (2) female with asymmetrical prosome; (3) female genital compound somite with lateral expansions and asymmetrical; (4) fifth legs of both sexes with rounded process distolaterally on the first endopodal segments; (5) male left leg 5 inner terminal spine present on the third exopodal segment; and (6) male right leg 5 with an outer spine at about midlength along recurved tip of the third exopodal segment. *Centropages acutus* McKinnon & Dixon, 1994 from Papua New Guinea also probably belongs to the *alcocki* group. Although it has several unique (probably autapomorphic) characters in the cephalosome, urosome and antennules, the structures of the fifth legs of both sexes of *C. acutus* display a more or less close relationship to the *alcocki* group. Chiba (1956) also described *C. pacificus* Chiba, 1956 from the Marshall Islands in the central Pacific, but this species was treated as a *species inquirenda* by Vervoort (1964).

The *alcocki* group seems to have a distribution restricted to the coastal waters of the tropical/subtropical Indo-West Pacific region (cf. Sewell 1912, Chen & Zhang 1965, Wellershaus 1970, Haq & Fazal-Ur-Rehman 1973, Mulyadi 2004). The zoogeography of this species group gives a hint on the origin of *Centropages maigo* found from the Pacific coast of the mainland of Japan. According to Nishimura (1981), a species or a species group exhibiting this distribution pattern probably originated from a tropical center of Southeastern Asia in the Indo-Malayan region. Some species groups of calanoid copepods from the Indo-West Pacific coastal area show such a distribution pattern in tropical/subtropical Asian waters with northern and southern extensions to northern Japan and northern Australia, respectively (Fleminger 1986, Ohtsuka et al. 1987, Ohtsuka & Kimoto 1989, Ohtsuka & Reid 1998). If it is supposed that *C. maigo* was sampled from its native habitat—the type locality, it can be regarded as the northernmost species of the species group. However, this new species has never been recorded before nor since its discovery in 1979, suggesting that it may not be a natural inhabitant of the region. This hypothesis is strongly supported by the fact that *C. maigo* has been collected only once (1 November 1979) in spite of intensive, weekly collections of zooplankton at the

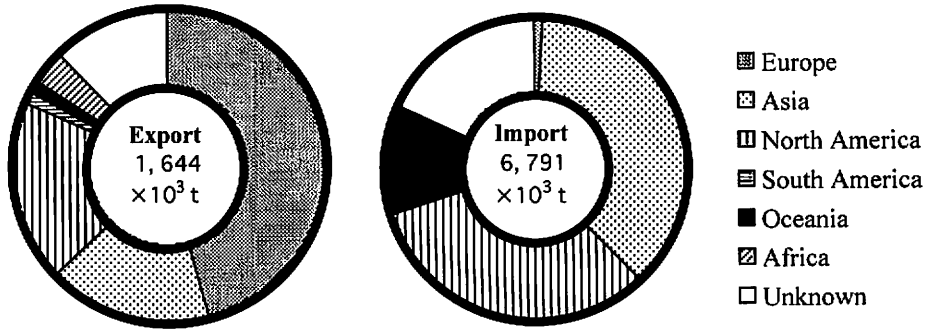

Fig. 4. Area composition of cargo for exports and imports in Shimizu Port in the year 1979 after Statistical year book of Shimizu Port (1978–1979) (Shimizu Port Authority 1980).

type locality from April 1979 to June 1980 (Itoh et al. 2005).

Five temperate species of the genus *Centropages* are known to have diapause eggs (Grice & Marcus 1981, Madhupratap et al. 1996, Marcus & Lutz 1998). If *C. maigo* produced diapause eggs, its benthic and planktonic phases would appear during the cold- and warm-water seasons, respectively, considering its possible origin in the tropical/subtropical regions. Even if so, the occurrence of planktonic adults of *C. maigo* at the type locality would be expected to occur, at least for several months in summer and fall as in other warm-water calanoid copepods that produce diapause eggs for overwintering (cf. Grice & Marcus 1981), and not be so limited in time.

Another possibility is that a temporary pseudo-population extended to Shimizu via the Kuroshio Current from the southern populations of the new species originally inhabiting tropical/subtropical areas of East Asia (cf. Nishimura 1981). Many invertebrate larvae and fishes such as *Acanthaster planci* and *Diodon holocabthus* are reported to be transported to the Pacific coasts of Japan by the Kuroshio Current from tropical/subtropical regions (e.g., Nishimura 1981, Yamaguchi 1986, 1987). However, this proposition can not explain why this species has not been collected from other localities along the Pacific coasts of Japan that are also influenced by warm currents.

The third possibility is that the new species could have been introduced from a tropical/subtropical Indo-West Pacific area via ballast water. The type locality, Shimizu, has a commercially important port which is frequented by many container and bulk ships from all over the world. During the year 1979, the export and import through container and bulk ships reached 1,644,000 and 6,791,000 t, respectively (Shimizu Port Authority 1980). In particular, exports to Asian countries (China, Pakistan, Indonesia, Malaysia, Thailand etc.) occupied about 17% (Fig. 4) and ships from these countries mostly carried ballast water that was discharged in the port. The new species found in Shimizu Port could have been accidentally introduced from subtropical/tropical Asian waters through the discharge of such ballast water. This hypothesis is enhanced by the fact that alien sessile organisms such as the barnacle *Balanus eburneus* and the bivalve *Mytilopsis sallei* were also first found from Shimizu Port in 1977 and 1979, respectively (Kosaka & Ishibashi 1979; Ishibashi & Kosaka 1980), indicating the potential for introductions of pelagic species. In San Francisco estuaries some planktonic copepods, introduced from East Asia, have established populations since introduction, whereas other species have disappeared soon after introduction (Orsi & Ohtsuka 1999). The new species *Centropages maigo* might also have failed to establish a population in its new locality.

So far there had been no records of alien copepods being introduced to Japan (Ohtsuka et al. 2004). This study may be the first record of occurrence of an alien planktonic copepod in Japan. Some alien species of not only marine but also terrestrial organisms have been described as new taxa at introduced localities (cf., Fukuda 2004). For planktonic copepods the originally Asian species, *Oithona davisae* Ferrari & Orsi, 1983 (cf. Nishida 1985), was described as a new species from a receiving area, San Francisco, CA, U.S.A. (Ferrari & Orsi 1983). According to Fukuda (2004), alien species are not always common species at the donor area. *Centropages maigo* may not be so common somewhere in subtropical/tropical Asian waters. Hence detailed, long-term faunal and floral surveys are needed to reveal whether this newly discovered species from coastal and brackish waters has been or could again be introduced via ship ballast water.

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