A NEW GENUS AND SPECIES OF PHTISICIDAE (CRUSTACEA: AMPHIPODA) FROM ABYSSAL DEPTHS IN THE JAPAN TRENCH, WITH SPECIAL REFERENCE TO SIMILARITIES WITH SOUTHERN OCEAN GENERA

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ABSTRACT

Abyssododecas styx, a new genus and new species of Phtisicidae (Amphipoda), is described based on specimens collected from cold-seep sites at abyssal depths between 5313 and 7322 m in the Japan Trench, North Pacific, using the crewed submersible Shinkai 6500 and the Remotely-Operated Vehicle Kaiko. This is the deepest yet record of a caprellidean amphipod. While A. styx n. gen., n. sp. looks like a member of Caprellidae, this species can be assigned to Phtisicidae through the possession of a normally articulated pereopod 3 and the lack of a molar on the mandible. The distribution of Phtisicidae along the coast of Japan, including deep-sea habitats, is rather rare, whereas genera of Caprellidae are dominant. Abyssododecas n. gen. is most closely-related to Dodecasella K. H. Barnard, 1931, which is distributed in the Southern Ocean, but differs in possessing a 2-articulated flagellum on antenna 2. The present discovery of Abyssododecas n. gen. from the North Pacific suggests a northward-trending distribution pathway over the ocean floor over geological time into the North Pacific through transport by Antarctic Bottom Water.

KEY WORDS: Antarctic Bottom Water, cold-seep fauna, Japan Trench, new genus, new species, taxonomy

INTRODUCTION

Caprellidean amphipods are small benthic crustaceans 1-3 cm in body length (Takeuchi et al., 2001). About 400 species have so far been recorded from the world’s oceans (Ahyong et al., 2011), and more than a quarter of these species have been found in and around Japanese waters (Mori, 1999; Takeuchi, 1999; Guerra-García and García-Gómez, 2003; Aoki and Ito, 2012; Takeuchi et al., 2014). Most caprellideans are found in algal beds, on gorgonians, buoys and on aquaculture facilities in the upper part of the subtidal zone (see Takeuchi et al., 2001; Scinto et al., 2008; Woods, 2009).

The deepest record for a caprellidean amphipod so far is Protoaeginella muriculata Laubitz and Mills, 1972 from 4970 m depth between Massachusetts and the Bermuda Islands in the North Atlantic (Laubitz and Mills, 1972). In addition to this species, about 60 species of caprellideans have been recorded from deep waters of more than 400 m depth (see McCain, 1966; Laubitz and Mills, 1972; Takeuchi et al., 1989; Vassilenko, 1993, 2009; Laubitz and Mills, 2001; Aoki and Ito, 2012; Takeuchi et al., 2014).

The deepest record of a caprellidean in the Pacific is for Abyssicaprella galatheae McCain, 1966 at depths of 3883-4004 m off Peru (McCain, 1966). The association of Caprella ungulina Mayer, 1903 with lithodid crabs has been widely reported from depths of 400-1200 m in Sagami Bay, central Japan, and also in the Sea of Okhotsk and off California (Wicksten, 1982; Takeuchi et al., 1989; Baldinger, 1992). Martin and Pettit (1998) reported a second species of Caprella Lamarche, 1801 to be associated with a lithodid crab, C. bathytatos Martin and Pettit, 1998, from a depth of 2201 m at hydrothermal vents at the Endeavor site on the Juan de Fuca Ridge off British Columbia, Canada. Nine species of Caprella and one species of Paracercops Vassilenko, 1972 have been recorded from the continental slope of the Kuril Islands, north-west Pacific, between 400 and 2200 m depth (Vassilenko, 1993), Guerra-García and García-Gómez (2003) described C. sabineae Guerra-García and García-Gómez, 2003 based on specimens collected from Sagami Bay, Japan, at 600 m, during the Dr. Sixten Bock Japan Expedition in 1914.

During research cruises on R/V Kairei and R/V Yokosuka, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), to cold-seep sites in the Japan Trench from 1999 to 2002, caprellidean amphipods were found on the muddy bottom at cold-seeps at depths of 5343-5379 m

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(Fujikura et al., 2002) and 7322 m (unpublished data), using the human occupied vehicle (HOV) Shinkai 6500 and the remotely-operated vehicle (ROV) Kaiko, a full ocean depth-rated ROV. These records are deeper than that for Protoaeginella muriculata in the North Atlantic (Laubitz and Mills, 1972). Subsequent studies revealed that this species is an undescribed species of the family Phthisicidae, and not a species of Caprella, which is the dominant genus that has so far been reported from deep waters in the northern Pacific. This caprellidean amphipod is herein described as Abyssododecas styx n. gen., n. sp. The biogeographical significance of the discovery of the present species is also discussed.

**MATERIALS AND METHODS**

The holotype was collected using a scoop held in the manipulator arm of the ROV Kaiko while sampling cold seep clams between 5695-5793 m depth during RV Kairei cruise KR99-03, ROV Kaiko Dive 111 (40°06.08′N, 144°10.02′E; Fig. 1) on 17 April 1999, and transferred to a lidded sample box for retrieval. Other specimens were also collected using a manipulator-held scoop on either the ROV Kaiko or the HOV Shinkai 6500 while sampling other seep-associated fauna. Video (NTSC) was recorded on DigiBetaCam tapes with data, including depth and local time, superimposed as text on the video image. The video record for each dive was reviewed using the original DigiBetaCam tapes (Sony HDW-M2100 HD Digital MultiPlayer, Sony HDTranslation, Color Monitor PHM-20M7I). Each video sequence was captured (AJA WZZ-KiPro2400) onto a hard disk cartridge (Quicktime container, ProRes 4:2:2 codec) via SDI. Captured files (.mov) were played back using Quicktime Pro version 7.6.6 and still images were extracted from the video files by viewing them at native magnification (Command 1 Actual Size), copying them to the clipboard (Command C Copy), creating a new file in Adobe Photoshop CC2014, and pasting them to the blank canvas (Command P Paste). The still images were then incorporated into the figure and saved as a TIFF file with no compression, IBM PC Byte Order and an interleaved pixel order.

Dissected mouthparts and appendages were stored on permanent slides mounted on gum-chloral medium. Methodology for making figure plates mostly followed Takeuchi (2015) by combining hand-drawn figures with digital inking. The original pencil sketches of the whole body in lateral view, antennae, gnathopods, pereopods, and mouthparts were first drawn under a microscope equipped with a camera lucida. Hand inked sketches were then drawn, using mapping pens, based on reduced copies of the original sketches. Hand-inked sketches were finally converted into digital files digital files using Adobe Photoshop CS6 (Adobe Systems).

Fig. 1. Sampling sites of Abyssododecas styx n. gen., n. sp., from the Japan Trench, North Pacific. The bathymetric map of the Japanese Archipelago was provided by the Marine Information Research Center, Japan Hydrographic Association.
The subordinal and familial classification of the present study, which is based on five families, Caprellidae, Caprogammaridae, Paracercopidae, Phitiscidae, and Cyamidae, follows Takeuchi (1993). The familiar classification was followed by Guerra-García and Takeuchi (2004), Lim et al. (2012), Takeuchi (2015) and Takeuchi and Lowry (2016). The setal formula, 1-×-y-1-z, for the setae on mandibular palp article 3 is modified from McCain (1968). This formula indicates the presence of one long seta on the apical part, a row/a number of short setae (x), a number of intermediate setae (y), 1 long seta on basal part, and a number of shorter setae out of 1 long seta on basal part (z). All type material is deposited in the National Science Museum, Tokyo, Japan (NSMT-Cr).

Taxonomy

Family Phitiscidae Vassilenko, 1968

_Abyssododecas_ n. gen.

Diagnosis.—Head fused (suture absent) with pereonite 1. Antenna 1 well developed; flagellum with more than 2 articles. Antenna 2 well developed; flagellum with 2 articles. Mandible well developed; molar absent; palp 3-articulate, setal formula 1-×-1-1 or 2. Maxilliped well developed; inner plate (basal endite) larger than outer plate (ischial endite); outer plate (ischial endite) well developed; palp article 3 with distal projection; palp article 4 well developed. Pereonite 4 claval appendage absent. Pereonites 6, 7 separated. Pereopod 3 well developed, with 7 articles. Pereopod 4 absent. Pereopod 5 reduced with 4 articles. Pereopods 6, 7 well developed, with 7 articles. Gills on pereonites 3 and 4. Uropods 1 pair, vestigial. Uropods 2 pairs; uropod 1 uniramous; uropod 2 uniramous. Telson (dorsal lobe) present.

Etymology.—The generic name _Abyssododecas_ is derived from _abyssos_, Greek for “deep sea” and _Dodecas_, generic name of one of the oldest genera of Phitiscidae.

Gender.—Feminine

Remarks.—Genera of Phitiscidae are characterized by a combination of several generic diagnostic traits, i.e., the absence of a mandibular molar; the palp of the mandible being 3-articulate; the head and pereonite 1 being completely fused; having three pairs of gills; gills on pereonites 2-4, pereonites 5 and 6 being separated and urosomites 1 and 2 being coalesced (see Takeuchi, 1993; Lim et al., 2012; Takeuchi and Lowry, 2016).

Among the genera in Phitiscidae, _Abyssododecas_ n. gen. is most closely related to _Dodecasella_ K. H. Barnard, 1931. _Dodecasella_ contains two species, _Dodecasella elegans_ K. H. Barnard, 1931, which was originally recorded from South Georgia in the sub-Antarctic region of the Southern Ocean (K. H. Barnard, 1931), and _Dodecasella georgiana_ (Schellenberg, 1931), described from specimens collected in Cumberland Bay, South Georgia (Schellenberg, 1931). Takeuchi (1993) presented a data matrix of morphological characters, given as codes, useful for clarification of the generic diagnoses of Caprellidae, and included data of _Dodecasella_ from Takeuchi and Takeda (1992), who re-described _Dodecasella elegans_ using specimens collected from off Princess Ragnhild Coast in Antarctica. A comparison of the description and figures of K. H. Barnard (1931), Takeuchi and Takeda (1992) and Takeuchi (1993), with the present material shows that _Abyssododecas_ n. gen. clearly differs from _Dodecasella_ by possession of a 2-articulated flagellum of antenna 2, instead of a more than 3-articulated flagellum of antenna 2 in _Dodecasella_, and 1-x-1-1 or 2 for the setae on mandibular palp article 3, instead of 1-x-1 as found in _Dodecasella_.

_Abyssododecas styx_ n. sp.

Figs. 2-5

Material Examined.—Holotype, male, NSMT-Cr 24369, 40°06.08′N, 144°10.02′E, 17 April 1999, 5695-5793 m depth, R/V Kairei, KR99-03, ROV Kaiko Dive 111. Paratypes, 1 male, 1 premature female, NSMT-Cr 24370, 40°06.08′N, 144°10.02′E, 17 April 1999, 5695-5793 m depth, R/V Kairei, KR99-03, ROV Kaiko Dive 111; 1 male, NSMT-Cr 24371, 39°06.5′N, 143°53.4′E, 15 June 2000, 5343 m depth, R/V Yokosuka, Leg 2 of YK00-04, HOV Shinkei 6500 Dive 550; 1 mature female, NSMT-Cr 24372, 39°06.431′N, 143°53.478′E, 24 July 2002, 5352 m depth, R/V Kairei, KR02-09, ROV Kaiko Dive 258. Additional material, 1 male, 1 immature female, 6 juveniles, 39°06.625′N, 143°53.355′E, 15 July 2002, 5313 m depth, R/V Kairei, KR02-09, ROV Kaiko Dive 254; 3 mature females, 1 premature female, 1 immature female, 4 juveniles, 39°06.431′N, 143°53.478′E, 24 July 2002, 5352 m depth, R/V Kairei, KR02-09, ROV Kaiko Dive 258; 1 juvenile, 40°02.751′N, 144°16.314′E, 25 July 2002, 7322 m depth, R/V Kairei, KR02-09, ROV Kaiko Dive 259.

Type Localities.—Japan Trench; 40°06.08′N, 144°10.02′E, 5695-5793 m depth (holotype); 39°06.5′N, 143°53.4′E, 5343 m depth; 39°06.625′N, 143°53.355′E, 15 July 2002, 5313 m depth, R/V Kairei, KR02-09, ROV Kaiko Dive 254; 3 mature females, 1 premature female, 4 juveniles, 39°06.431′N, 143°53.478′E, 24 July 2002, 5352 m depth, R/V Kairei, KR02-09, ROV Kaiko Dive 258; 1 juvenile, 40°02.751′N, 144°16.314′E, 25 July 2002, 7322 m depth, R/V Kairei, KR02-09, ROV Kaiko Dive 259.

Etymology.—The new species is named after the River Styx, which forms the boundary between Earth and the Underworld in Greek mythology, also alluding to the abyssal “river” proposed to have transported its ancestors from the Southern to the Northern Hemisphere.

Description.—Holotype (Fig. 2), male, NSMT-Cr 24369, body length, 32.80 mm. Head, pereonite 1 combined, body length; peduncular article 1 with single line of apical setae. Maxilla 1 outer plate (basal endite) well developed; in- ter plate (ischial endite) larger than outer plate (ischial endite); outer plate (ischial endite) well developed; palp article 3 with distal projection; palp article 4 well developed. Pereonite 4 claval appendage absent. Pereonites 6, 7 separated. Pereopod 3 well developed, with 7 articles. Pereopod 4 absent. Pereopod 5 reduced with 4 articles. Pereopods 6, 7 well developed, with 7 articles. Gills on pereonites 3 and 4. Pleopods 1 pair, vestigial. Uropods 2 pairs; uropod 1 uniramous; uropod 2 uniramous. Telson (dorsal lobe) present.

Mouthparts (Fig. 4). Upper lip wider than deep, bilobed. Lower lip, inner lobe round. Mandible left incisor with 4 teeth, lacinia mobilis with 6 teeth followed by single line of setae; molar lacking; palp 3-articulate; article 2 3.0 × article 1, with 10 lateral, 1 distal setae; article 3 0.8 × article 2, with setal formula of 1-19-1-2. Mandible right setal formula 1-25-1-1. Maxilliped 3 well developed, with 7 articles. Antenna 1 (Fig. 2) 0.55 × body length; peduncular length, 3.0 × article 1; article 3 0.9 × article 2; flagellum 0.4 × peduncular length with 12 articles; proximal segment composed of 7 articles. Antenna 2 (Fig. 3) 0.3 × antenna 1 length; flagellum 0.25 × peduncular length, with 2 articles.

Type Localities.—Japan Trench; 40°06.08′N, 144°10.02′E, 5695-5793 m depth (holotype); 39°06.5′N, 143°53.4′E, 5343 m depth; 39°06.625′N, 143°53.355′E, 15 July 2002, 5313 m depth, R/V Kairei, KR02-09, ROV Kaiko Dive 254; 3 mature females, 1 premature female, 4 juveniles, 39°06.431′N, 143°53.478′E, 24 July 2002, 5352 m depth, R/V Kairei, KR02-09, ROV Kaiko Dive 258; 1 juvenile, 40°02.751′N, 144°16.314′E, 25 July 2002, 7322 m depth, R/V Kairei, KR02-09, ROV Kaiko Dive 259.

Etymology.—The new species is named after the River Styx, which forms the boundary between Earth and the Underworld in Greek mythology, also alluding to the abyssal “river” proposed to have transported its ancestors from the Southern to the Northern Hemisphere.
**Abyssododecas styx** n. gen., n. sp., holotype, male, NSMT-Cr 24369, 32.80 mm, and paratype, female, NSMT-Cr 24372, 22.52 mm, Japan Trench.

Inner plate with 15 setae; outer plate with ca. 15 apical setae. Maxilliped inner plate (basal endite) with 2 stout setae on inner half of distal margin, with 2 setae on outer half of distal margin; outer plate (ischial endite) 0.9 × inner plate (basal endite) with 6 stout setae on inner margin; palp 4-articulate, article 2 longest, setose along entire inner margin; article 3 1.5 × article 1, 1 row of lateral setae, setose on distal part; dactylus falcate.

**Pereon (Figs. 2, 3).** Gnathopod 1 basis longest, 1.4 × ischium, merus, carpus combined; carpus subtriangular, densely setose; propodus triangular, length 1.3 × width, with 7 rows of lateral setae; palm begins <1/10 along posterior margin; proximal projection equipped with single robust seta followed by 5 stout setae along palm; dactylus falcate. Gnathopod 2 begins 1/4 along posterior margin of pereonite 2; basis, 1.3 × pereonite 2 length; propodus longer than wide (length 1.5 × width); palm begins 2/5 along posterior margin, proximal projection with single robust seta (grasping spine) followed by 2 normal setae; palm with triangular projection near anterior end with shallow sinus, single row of small teeth between proximal projection, sinus.

Gill 3 length 0.5 × pereonite 3, oval. Pereopod 3, 3.60 mm, short, 0.10 × body length; basis longest, 0.35 × pereopod 3 length; ischium 0.20 × basis; merus 0.45 × basis; carpus 0.55 × basis; propodus straight, shorter than carpus with several setae; dactylus falcate. Gill 4 subequal with gill 3.

Pereopod 5, 3.19 mm, slender, 0.9 × pereopod 3 length; articulation between articles 1, 2 oblique; propodus longest; dactylus falcate. Pereopod 6, 7 slender, elongated. Pereopod 6 8.62 mm, basis, 0.20 × pereopod 6 length; ischium 0.15 × basis; merus 0.65 × basis; carpus 0.85 × basis, setose along entire inner margin; propodus longest, with single spine 1/8 from posterior margin on palm followed by ca. 10 setae; dactylus falcate. Pereopod 7, 9.23 mm, longer than pereopod 6 (1.1 × longer).

**Pleon.** (Fig. 3). Pleopod base with 7 setae, vestigial fused with single seta distally. Uropod 1 elongated, 0.75 mm; peduncle elongated (length 8 × width); ramus short, 0.20 × peduncular length. Uropod 2 base with 2 setae, 0.53 mm; peduncle, 2.8 × width; ramus, 0.20 × peduncular length. Telson small, with pair of minute setae.

Paratype (Figs. 2 and 5), female, NSMT-Cr 24372, body length, 22.52 mm; body somites slender. Head and pereonite 1 combined, 2.33 mm, completely fused, suture absent. Length of pereonites 2-7, 2.78 mm, 3.09 mm, 4.02 mm, 5.11 mm, 4.50 mm, 0.69 mm, respectively. Pereonite 2 with anterolateral round, anteriorly curved mid-lateral projections. Pereonite 3 with anterolateral round, mid-lateral, posterior lateral projections. Pereonite 4 with anterolateral round, mid-lateral projections.

**Antenna 1 0.5 × body length; peduncular article 3 longest, 0.4 × antenna 1; flagellum 0.30 × peduncular length with 8 articles. Gnathopod 2 begins 1/5 along posterior margin of pereonite 2; basis, 1.1 × pereonite 2 length; propodus longer than wide (length 1.5 × width); palm begins 1/3 along posterior margin; palm with shallow triangular projection. Pleopod vestigial, base with 3 setae. Uropod 1 elongated; peduncle elongated (length 10 × width); ramus short, 0.20 × peduncular length. Uropod 2 0.7 × uropod 1 length; peduncle, 5.0 × width; ramus, 0.30 × peduncular length.
Fig. 3. *Abyssododecas styx* n. gen., n. sp., holotype, male, NSMT-Cr 24369, 32.80 mm, Japan Trench; A, antenna; ABD, abdomen; G, gnathopod; P, pereopod.
Abyssoidecas styx n. gen., n. sp., holotype, male, NSMT-Cr 24369, 32.80 mm, Japan Trench; LL, lower lip; MD, mandible, MX, maxilla; MXPD, maxilliped; UL, upper lip; L, left; R, right.
Ecology and Behavior.—The fauna at the cold-seep site was surveyed during the HOV *Shinkai 6500* Dive 550; species that were visible in the video record included the seep clam *Calyptogena phaseoliformis* Métivier, Okutani and Ohta, 1986 and the buccinid snail *Bayerius arnoldi* (Lus, 1981).

The benthic fauna on the mud and/or rocky outcrops surrounding the seep site included both burrowing (*Iosactis* sp.) and stalked anenomes, goniasterid, and pedicellasterid (cf. *Ampheraster* Fisher, 1923) starfishes, ophiuroids, holothuroids (*Scotoplanes globosa* Théel, 1879 and *Enypniastes eximia* Théel, 1882), stalked ascidians (*Phlebobranchia*), and long-stalked crinoids. Caprellid amphipods only occurred at the cold seep site, suggesting they may be endemic to this environment.

The new species herein described resembled members of Caprellidae (Fig. 6) when we observed specimens without using a binocular microscope. The flagellum of antenna 2 is 2-articulated, typical for Caprellidae. Pereopod 3 is relatively small, 1/10 of the body length for Phitiscidae, while pereopod 3 is 7-articulated, just as in most amphipod crustaceans.

*Abyssododecas styx* n. gen., n. sp. kept an upright posture *in situ*, one of the dominant clinging behaviors defined by Takeuchi and Hirano (1995). While the segment from the head to pereonite 5 of the body somites was bent anteriorly, pereopod 5, which is smaller than pereopod 3, was generally held out laterally without clinging to the substrate. The posterior body somites, pereonites 6 and 7, were held vertically with the posterior extreme of pereonite 7, possibly in contact with the sediment, and with pereopods 6 and 7 anchoring to the sediment at an angle of about 90° to...
each other. The clinging behavior of the new species is very close to that of *Parvipalpus major* Carausu, 1941, which was collected from bathyal muddy sediments at a depth of 424-761 m in the Bay of Biscay, Atlantic Ocean (Cortabani et al., 2005). *Parvipalpus* Mayer, 1890 (Caprellidae) is distributed widely in the Atlantic, from shallow waters to 1007 m (McCain and Steinberg, 1970; Guerra-García, 2003; Cortabani et al., 2005).

Remarks.—The present record is the deepest occurrence of a caprellidean amphipod. Only three species of caprellidean had been previously recorded from depths greater than 4000 m. Laubitz and Mills (1972) described *Protoaeginella muriculata* from the Gay Head, MA, USA to the Bermuda transect at 1330-4970 m depth and *Thovina elongata* Laubitz and Mills 1972 from the same transect at 1500-4892 m depth. *Abysscaprella galatheae* was recorded from 3883-4004 m off Peru and 3501-3570 m off Costa Rica in the eastern Pacific (McCain, 1966). Of 45 genera of Caprellidae coded in Takeuchi (1993), compared with the eastern Pacific (McCain, 1966). Of 45 genera of Caprellidae coded in Takeuchi (1993), compared with *Caprella*, the three genera from abyssal depths possess rather primitive generic characters (Takeuchi, 1993).

**DISCUSSION**

Although *Abbyssododecas styx* n. gen., n. sp. superficially resembles members of *Caprellidae*, the family that dominates the Japanese caprellidean fauna, it belongs instead to Phthisciidae within the four families of benthic caprellideans. About 110 species of benthic caprellideans had been recorded from Japan and adjacent areas by 2015 (Mori, 1999; Takeuchi, 1999; Guerra-García and García-Gómez, 2003; Aoki and Ito, 2012; Takeuchi et al., 2014). Of these, only eight species belong to Phthisciidae, with Caprellidae comprising more than 80% of the total number of recorded species of caprellideans (Takeuchi, 1999). *Caprella* is the dominant genus in Japanese waters, constituting more than 75% of the species of Caprellidae. Only two species of *Caprella* are known in waters deeper than 400 m around Japan (Takeuchi et al., 1989; Guerra-García and García-Gómez, 2003), whereas members of Phthisciidae have not yet been reported from Japanese waters below depths of 400 m.

In contrast, in the Antarctic and sub-Antarctic region the number of species of Phthisciidae is almost equal to that of Caprellidae based on the literature published until 2003 (De Broyer et al., 2004).

*Abbyssododecas* n. gen. from the Japan Trench possesses several unique characters. While pereopod 3 has a normal segmentation as in most Amphipoda, pereopod 4 is degenerated. While phthisciid genera that possess this character have not yet been reported from the North Pacific, *Abbyssododecas* is very similar to the phthisciid *Dodecasella* from the Southern Ocean (Figs. 7 and 8).

Two species are currently included in *Dodecasella*. *Dodecasella elegans*, the type species, is known from South Georgia in the sub-Antarctic and along the Antarctic coast (De Broyer et al., 2004). *Dodecasella georgiana*, the second species, is distributed along the southern coast of South America and in the sub-Antarctic. The depth range of these species of *Dodecasella* is 68-2894 m (De Broyer et al., 2004).

*Dodecas* Stebbing, 1883 is most similar to *Dodecasella*, presumably being the primitive condition. *Dodecas* was established based on *D. elongata* Stebbing, 1883 from Kerguelen in the Indian Ocean sub-Antarctic region. Seven species so far belong to this genus: *D. decacentrum* Stebbing, 1910; *D. elongata*; ?*D. eltaninae* McCain and Gray, 1971; *D. grandimanus* Guiler, 1954; *D. hexacentrum* Mayer, 1903; *D. reducta* K. H. Barnard, 1932, and *D. tasmaniensis* Guiler, 1954. Of these species, three (*D. elongata*, ?*D. eltaninae*, and *D. reducta*) are distributed from southern South America to the sub-Antarctic (Fig. 7). The depth range of these sub-Antarctic *Dodecas* species is 24-210 m (De Broyer et al., 2004). The remaining four species were recorded from shallow waters along the coasts of Australia, from Tasmania to New South Wales and Western Australia, Australia (Fig. 7).

A comparison of generic characters suggests a phylogenetic net as follows: *Dodecas*-*Dodecasella*-*Abbyssododecas* (Fig. 8). Takeuchi (1993) identified and codified 12 major characters useful in the diagnoses of the 23 genera of Phthisciidae. With respect to these 12 major characters proposed by Takeuchi (1993), *Abbyssododecas* possesses the apomorphic, or derived, character of the number of articles in the flagellum of antenna 2 having regressed to be 2-articulated, rather than three- or more-articulated as in *Dodecasella* (see above). *Dodecasella* is most closely aligned with *Dodecas*, and the distribution of *Dodecasella* and *Dodecas* overlap in the cold waters of the Southern Hemisphere. Compared with *Dodecas*, *Dodecasella* possesses an apomorphic or derived character in the number of gills, having one pair on each of pereonites 3 and 4 in *Dodecasella*, instead of a pair on each of pereonites 2, 3, and 4 in *Dodecas*.

*Pseudododecas* McCain and Gray, 1971 is also a genus closely related to *Dodecasella* (Fig. 8). The major difference is that *Pseudododecas* has a reduced articulated pereopod 3, whereas pereopod 3 of *Dodecasella* is 7-articulated, as in *Abbyssododecas* and *Dodecas*. *Pseudododecas bowmani* McCain and Gray, 1971, the only known species of *Pseudododecas*, was recorded at 325-769 m near the South Shetland Islands (De Broyer et al., 2004).

It is of great interest to understand why *Abbyssododecas*, a genus closely related to genera from the Southern Ocean, is found at abyssal depths in the Japan Trench in the North Pacific (Fig. 8). Previous studies on the benthic fauna of deep-sea chemosynthetic ecosystems around Japan have not yet described, or perhaps not compared, any similarities with the same type of fauna in the Southern Ocean. Nakajima et al. (2014) analyzed 42 benthic macro- and megafauna from deep-sea chemosynthetic ecosystems around the Japanese Archipelago and found that the composition of assemblages at three West Kuril to Japan Trench sites were similar to each other. The molluscan assemblages of cold-seep communities in the Japan Trench have also been reported to be similar at the familial and generic levels to those of cold-seep communities elsewhere in the Pacific, especially the fauna in the Aleutian Trench subduction zone (Fujikura et al., 2002).

Recent oceanographic studies indicate that the Antarctic Bottom Water flows into the North Pacific via the Samoan Passage, a 40-km-wide notch between the Samoan Basin and the Central Pacific north of New Zealand. The Kerguelen Deep Western Boundary Current, originating near the
Fig. 7. Worldwide distribution of *Abyssododecas* n. gen. and the three related genera, *Dodecas*, *Dodecasella*, and *Pseudododecas* (Phtisicidae). Data from Guiler (1954), De Broyer et al. (2004), Guerra-García (2004b), Guerra-García and Takeuchi (2004), Vassilenko (2006), Takeuchi and Lowry (2016), and the present study. Lines indicate the movement of deep currents originating from the Antarctic Bottom Water on the ocean floor based on Dacey (2010).

Fig. 8. Proposed phylogeny of *Abyssododecas* n. gen., *Dodecas*, *Dodecasella*, and *Pseudododecas*. The lateral-view figures of *Dodecas*, *Dodecasella*, and *Pseudododecas* were redrawn from Takeuchi and Lowry (2016), Takeuchi and Takeda (1992), and Laubitz (1991), respectively. The distributions for these four genera are from Guiler (1954), De Broyer et al. (2004), Guerra-García (2004b), Guerra-García and Takeuchi (2004), Vassilenko (2006), Takeuchi and Lowry (2016), and the present study.
Kerguelen Plateau, is the primary path for the transport of Antarctic Bottom Water into the global ocean’s deep overturning circulation (Fukamachi et al., 2010). The Kerguelen Plateau is situated in the Southern Ocean in the Indian Ocean Sector. This current is remarkably fast for abyssal depths, exceeding 20 cm/s at about 3500 m depth. Alford et al. (2013) reported direct turbulence observations in the Samoan Passage, through which most of the water supplying the North Pacific abyssal circulation flows. The flow reaches speeds as great as 55 cm s\(^{-1}\) within the Samoan Passage. This indicates that cold bottom water from the South Pacific, originating from the Antarctic Bottom Water, passes through the Samoan Passage flowing along the ocean floor into the North Pacific. Moreover, Fukazawa et al. (2004) noted that the bottom water from the Samoan Passage flows into the Northwest Pacific basin near the Mariana Trench and into the Japan Trench, where A. styx was collected. In the global distribution maps of seawater temperature at 1000 m intervals, cold deep waters with temperatures close to 2°C spread over the North Pacific from around the Samoan Passage to the Japan Trench at 5000 m depth, whereas the deep water of the North Atlantic at the same abyssal depth is warmer, more than 2°C (see Yasuhara and Danovaro, 2014: fig. 1F).

The possibility therefore exists that the ancestor(s) of Abyssododecas extended their distribution northwards and into abyssal depths, reaching the North Pacific, by way of the northwards-flowing Antarctic Bottom Water, which presumably started forming after the Antarctic continent separated and the Antarctic Circumpolar Current fully developed around 21-34 million years ago (mya) based on Late Cretaceous to Present plate reconstructions derived from a global database compiled by the PLATES project at the University of Texas at Austin (Lawver et al., 2014).

The geological period after the formation of the Antarctic Circumpolar Current corresponds to the generic and/or species divergence periods of the marine Amphipoda based on molecular analysis. Among the deep-sea gammarideans in the North Atlantic, the feeding shift from “opportunist” scavenger to “obligate” and “specialised” ones occurred independently 40, 33, and 20 mya (Corrigan et al., 2014). White et al. (2016) estimated that evolutionary age of Leucothoe vulgaris White and Reimer, 2012 (Amphipoda, Leucothoidae) with related species of the same genus as 21.0-34.9 mya based on the analysis of COI mitochondrial DNA gene sequences. Leucothoe vulgaris is an endemic species of benthic amphipods inhabiting ascidians, sponges, and coral rubble along the coast of the Ryukyu Archipelago, southwestern Japan.

Because caprellideans lack a planktonic larval stage and have a clinging lifestyle as shown by the reduced abdominal appendages that are used for swimming in other amphipods (Takeuchi et al., 2001), one might think that their distribution along the bottom at abyssal depths would be limited. The attachment of Caprella spp. to larger invertebrates, which exhibit greater mobility, has been reported from bathyal to abyssal depths. Caprella unguilina and C. bathytatus attach to species of several genera of lethid crab, including Lithodes Latreille, 1806, Macregonia Sakai, 1978, and Paralomis White, 1856, at depths of 400-2200 m (Wicksten, 1982; Takeuchi et al., 1989; Baldinger, 1992; Martin and Pettit, 1998; Sittrop and Serejo, 2006; Verdi and Clentano, 2008). Lithodes ferox Filhol, 1885, which inhabits depths of 300-1000 m off the west coast of Africa, was reported to migrate seasonally to different bathymetric depths off southern Namibia (Abelló and Macpherson, 1991). Caprella subtilis Mayer, 1903 was recorded from 309 m attached to a swimming benthopelagic holothurian, Ellipinion kunai (Mitsukuri, 1912), in Sagami Bay, Japan (Lindsay and Takeuchi, 2008). Rogacheva et al. (2012) reported the swimming behavior of deep-sea holothurians at abyssal depths of 2200-2800 m in the northern Mid-Atlantic Ridge. Ellipinion Hérouard, 1923 is categorized as a “frequent swimmer (often swimming, but spending most of its time on the seafloor)’ and has been observed from various habitats from sedimentary plains to steep slopes with talus (Rogacheva et al., 2012). Porepods 5-7 of C. subtilis, which are used to hold on to its holothurian host, are elongated like those of Abyssododecas. This similarity suggests the possibility that Abyssododecas also attaches to gelatinous zooplankton or other invertebrates in order to move between cold-seep sites that are geographically removed. During or following this northward extension of their range, these phitids amphipods from the Pacific Ocean evolved convergently to resemble the Atlantic caprellid Parvipalpus, both with a reduced number of articulated in the flagellum of antenna 2 and a reduced size of pereopod 3.

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