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Validation and redescription of *Cymbasoma germanicum* (Timm) (Crustacea: Copepoda: Monstrilloida) from Helgoland with comments on *Cymbasoma rigidum* Thompson

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Abstract Reexamination of a monstrilloid copepod collected in 1892 at Helgoland, Germany and deposited in the Zoological Museum (Berlin) offered the opportunity of (1) providing a complementary redescription of *Cymbasoma germanicum* (Timm) from its type locality, and (2) reviewing the taxonomical status of *Cymbasoma rigidum* Thompson 1888, and its presumed cosmopolitan distribution. *Cymbasoma germanicum* can be distinguished from the different morphotypes related to the nominal species *C. rigidum* by a combination of characters, including a large inner lobe of the fifth leg, an innermost fifth leg seta almost as long as the other two, the relative length of the antennules, and the presence of long elements 2v and 2d on the second antennular segment. The main distinguishing character is the presence of two knob-like processes on the posterior margin of the genital somite. Based on differences in several characters but mainly on the taxonomically important structure of the fifth legs, at least three distinct morphological patterns were detected among the main historical records of *C. rigidum*. This variability, the uncertainty of the identity of the original specimen, and the geographic amplitude of the records of *C. rigidum* suggest that the nominal species represents a taxonomic complex with several undescribed taxa.

Keywords Invertebrate taxonomy · Copepods · Distribution

Introduction

Monstrilloid copepods are in urgent need of revision (Huys and Boxshall 1991); recent efforts have clarified some of the nomenclatorial and taxonomic problems

related to the definition of the genera of Monstrilloida (Grygier 1994a; Suárez-Morales and Gasca 2004; Grygier and Ohtsuka 2005). There are, however, many unsolved problems on the species level. The earliest taxonomic descriptions of species of monstrilloids have been very variable in terms of detail, extension, and quality. Upgraded morphological descriptions of type and old specimens are needed in order to conduct a taxonomic revision of this group. Reexamination of these old specimens presents all kind of difficulties but some controversies have been disentangled (Grygier 1994a, b; Suárez-Morales 2000, 2001; Suárez-Morales and Ivanenko 2004).

One of the problems to be addressed in the taxonomy of the genus *Cymbasoma* is the apparent cosmopolitanism of some widely distributed species. A closer look at these nominal species, such as *C. longispinosus* (Bourne 1890) has proved that they represent species complexes formed by closely related forms (see Grygier 1994; Suárez-Morales and Escamilla 1997; Suárez-Morales and Palomares 1999). Another species with a presumed cosmopolitan distribution is *C. rigidum* Thompson 1888 (Isaac 1975). Records of this nominal species are known from a wide variety of environments and geographic locations including tropical, temperate, and subarctic latitudes (see Isaac 1974; Grygier 1995; Dias 1996; Bernier et al. 2002).

A well-preserved female specimen collected in 1890 in Helgoland and deposited in the collection of the Zoological Museum (Museum für Naturkunde, Berlin) was originally identified as *Thaumaleus germanicus* (Timm 1893). Eighty-four years later, the same specimen was re-identified and labeled as *C. rigidum* by Isaac (1974) following Sars' (1921) opinion that *Cymbasoma germanicum* (as *T. germanicus*) is a synonym to *C. rigidum*. In an attempt to recover information about these old and scarce monstrilloid specimens, this unique female specimen was reexamined. It is fully described herein following the upgraded standards for monstrilloid copepods descriptions set by Grygier and Ohtsuka (1995) and its taxonomical status is stated and discussed. Also,

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previous records of *C. rigidum* were revised in order to determine the status of this nominal species. Taxonomical comments and comparisons are made for both species based on the available information.

Methods

The specimen was received from the Museum für Naturkunde, preserved in ethanol. The appendages and setae were stiff and fragile. In order to facilitate the observation process, the specimen was transferred to freshly prepared 70% ethanol with glycerine added and then left in pure glycerine with a drop of methylene blue for 1 week. This process of mild staining allowed all the structures, particularly those on the cuticular surface, to become clearer under the light microscope. Drawings were prepared using a camera lucida at different magnifications. After the taxonomical examination and handling, the specimen was placed again in ethanol with a drop of glycerine thus allowing the methylene blue to fade from the tissues.

Results

Subclass Copepoda Milne-Edwards, 1830
 Order Monstrilloida Sars, 1903
Cymbasoma germanicum (Timm 1893)
 (Figs. 1, 2, 3, 4)

Material examined

Adult female, ethanol preserved, undissected. Plankton collection, Helgoland, Germany. Specimen collected 29 September 1892. Labeled originally as *T. germanicus* Timm. Additional label by M.J. Isaac correcting the name as *T. rigidus* (Thompson 1888). Specimen deposited in the Zoological Museum (Berlin), under cat. 14053.

Description of female

Total body length is 2.9 mm measured from anterior end of cephalic somite to posterior margin of anal somite. Cephalothorax incorporating first pedigerous somite slightly curved on dorsal view, probably a result of fixation, accounting for 58.3% of total body length (Fig. 1a, b). Forehead slightly rounded in dorsal view, with a small field of wart-like cuticular processes on the ventral surface; a pair of short sensillae between the antennule bases (Fig. 2d). Ventral surface of head with low, rounded convex protuberance between bases of antennules, visible in ventral view (Fig. 4e). One pair of well-developed nipple-like cuticular processes on ventral surface between antennule bases and oral papilla, both processes surrounded and connected by field of

transverse ridges (Figs. 2c, 4e). Oral papilla moderately protuberant, located close to anteriormost part of body, midventrally 0.24 of way back along cephalothorax (Figs. 1b, 2c). Nauplius eye present, well developed, ocelli relatively large, weakly pigmented, rounded, eyes separated by less than ½ eye diameters.

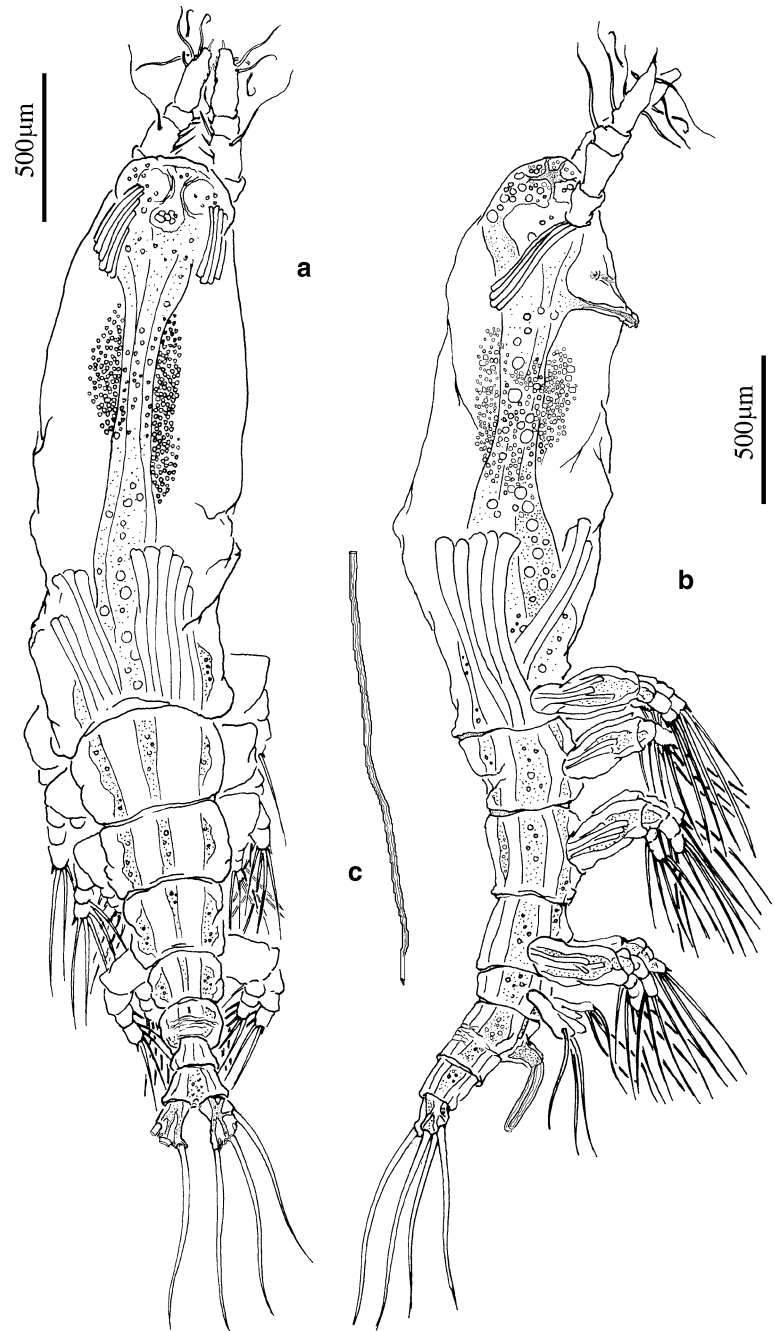
Antennules relatively long, slender, slightly shorter than 20% of total body length, and about 32% of length of cephalothorax. Antennule length 0.45 mm. Both antennules present in the specimen. As usual in female monstrilloids, antennules four segmented, intersegmental divisions well defined. Last antennular segment longest, representing 40% of total length of antennule; ratio of lengths of segments (proximal-distal): 24.3:25.5:10.2:40 = 100. Armature with 0,I (broken off on both sides, but sockets present); 1,V; 2,I; 6, VIII setae (Roman numerals) and spines (Arabic numerals) (Fig. 2a) plus two aesthetascs. Following pattern described by Grygier and Ohtsuka (1995) for monstrilloid antennular armature, setae and spines on first (1), second (2d₁₋₂, 2v₁₋₃, II_d), and third (3, III_v, III_d) segments complete. Fourth segment with 4v₁₋₃, IV_v, IV_d, 4d₁, V_m, V_d (possibly broken off), V_v (socket on left antennule, present on right antennule), 5, 6₁, 6₂ (sockets on both antennules), 4_{aes}, 6_{aes}, b₁₋₅; missing: b₆ (or at least one of the b-setal group). Setae b₁₋₅ branched distally.

Incorporated first pedigerous somite and three free succeeding pedigerous somites, each bearing pair of biramous swimming legs. Right third leg incomplete, with distal endopodal and exopodal segments broken off (Fig. 2c). Intercoxal sclerite on legs 1–4 rectangular, naked. Basis with diagonal division articulating it with large, rectangular coxa. Lateral hair-like setae usual on basis of legs 1–4 of the Monstrilloida present on legs 3 and 4 on studied specimen; as in other monstrilloids, basipodal seta on third leg noticeably longer and thicker than in the other swimming legs [8 times longer in leg 3 than in leg 4 in this specimen (Fig. 3d)]. Natatory legs setae all lightly and biserially plumose (setules not illustrated). Endopodites and exopodites of legs 1–4 triarticulated (Fig. 3a–d). Third exopodal segment with outermost terminal spiniform seta relatively short, between 1.6 and 2.5 times as long as bearing segment. Spiniform terminal setae of same segment armed with small spinules along outer margin; inner margin with short setules (Fig. 3a, b). Armature of swimming legs:

	Basis	Endopodite	Exopodite
Leg 1	1–0	0–1; 0–1; 1, 2, 2	I–1; 0–1; I, 1, 3
Legs 2–4	1–0	0–1; 0–1; 1, 2, 2	I–1; 0–1; I, 1, 2, 2

Fifth legs moderately long, one segmented, fused medially. Each leg represented by two lobes, outer lobe cylindrical, armed with three long, plumose seta, all

Fig. 1 *Cymbasoma germanicum* (Timm). Adult female from Helgoland. **a** Habitus, dorsal view; **b** habitus, lateral view; **c** ovigerous spine

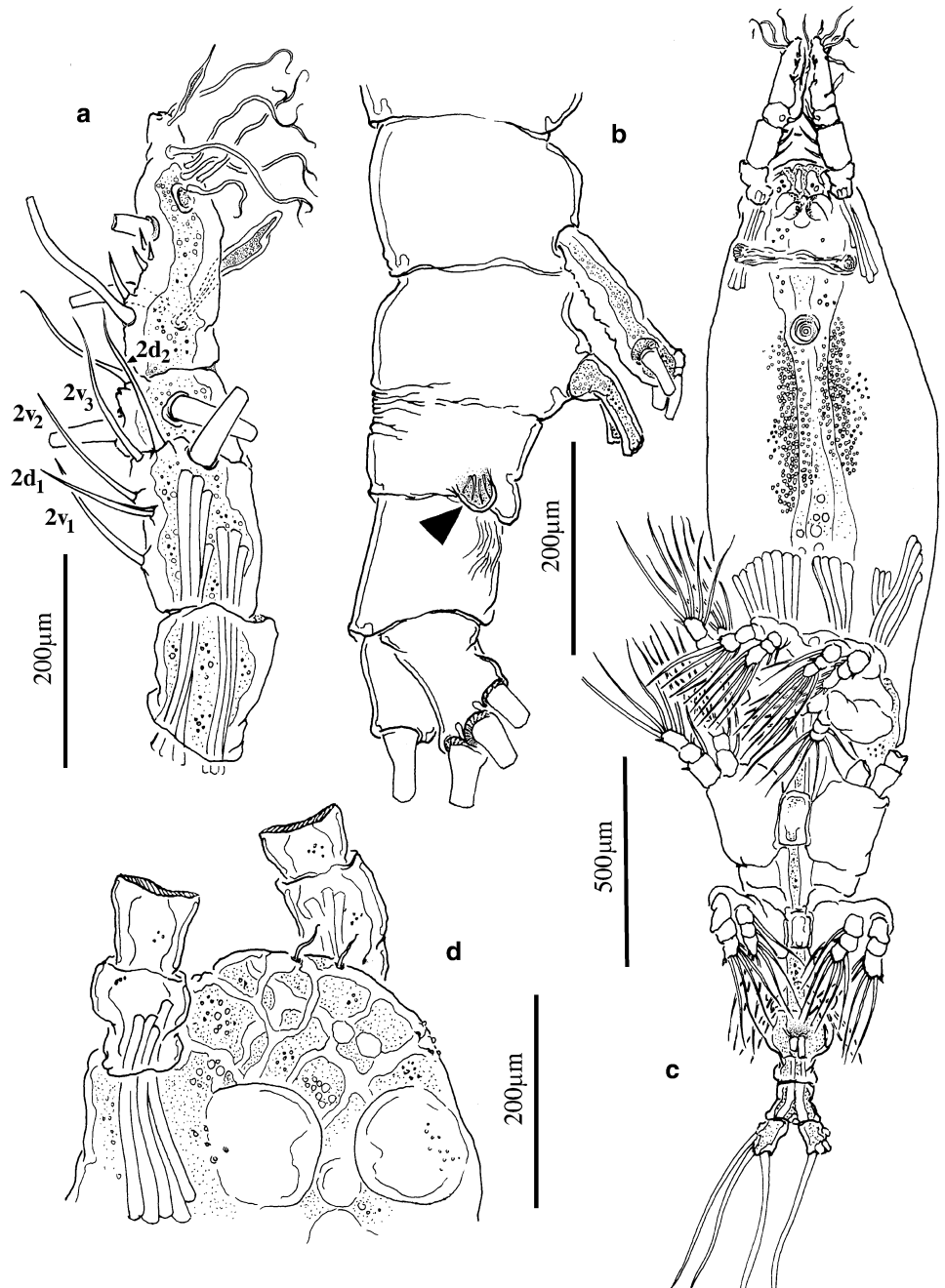


subequal in length and width, innermost slightly shorter, about 85% the length of the other two setae. Fifth leg setae reach distal margin of anal somite. Inner lobe separated from the main (outer) lobe from its proximal 1/3 section; inner lobe reaching the distal end of outer ramus of fifth legs (Figs. 3e, 4a–c).

Urosome consisting of fifth pedigerous somite, genital double somite, and one free abdominal somite. Urosome, excluding furcal rami, accounting for 16% of the total body length. Ratio of lengths of urosomites as (proximal distal): 28.5:48:23.5=100. Second to fourth pedigers accounting for 24% of the total length in dorsal view. Genital double somite pear-shaped,

proximal half strongly globose; somite representing almost half the length of the urosome (48%) (Fig. 4a, b, d). Genital double somite with partial intersegmental division running around about 1/2 of its circumference and visible in ventral surface; suture absent on dorsal surface (Fig. 4a), where it is substituted by field of transverse striae (Fig. 4a). Ventral anterior surface of genital double somite with rounded protuberance visible in lateral view (Fig. 4a). Distal margin of somite with two rounded processes, one on each lateral surface of somite (arrowed in Figs. 2b, 4a). Medial ventral part of genital double somite bearing relatively long (1.24 mm), basally separated ovigerous

Fig. 2 *Cymbasoma germanicum* (Timm). Adult female from Helgoland. **a** Right antennule showing some setal elements using setal nomenclature by Grygier and Ohtsuka (1995), dorsal view; **b** urosome, right lateral view showing lateral process (arrowed); **c** habitus, ventral view; **d** head, semi-dorsal view showing sensillae



spines (Fig. 1b), mostly slender but slightly swollen at distal end (Fig. 1c); spines representing about 43% of total body length, reaching well beyond distal end of caudal setae (Fig. 1b). Anal somite with moderately divergent lateral margins; somite with notch on middle of outer margins and array of longitudinal striae on ventral surface (Fig. 4b, d). Caudal rami subrectangular, about 1.5 times as long as wide, moderately divergent, bearing three setae arranged as two outer and one inner; setae on left ramus complete, those on right ramus broken off (Fig. 4d); inner caudal seta longest.

Male: unknown.

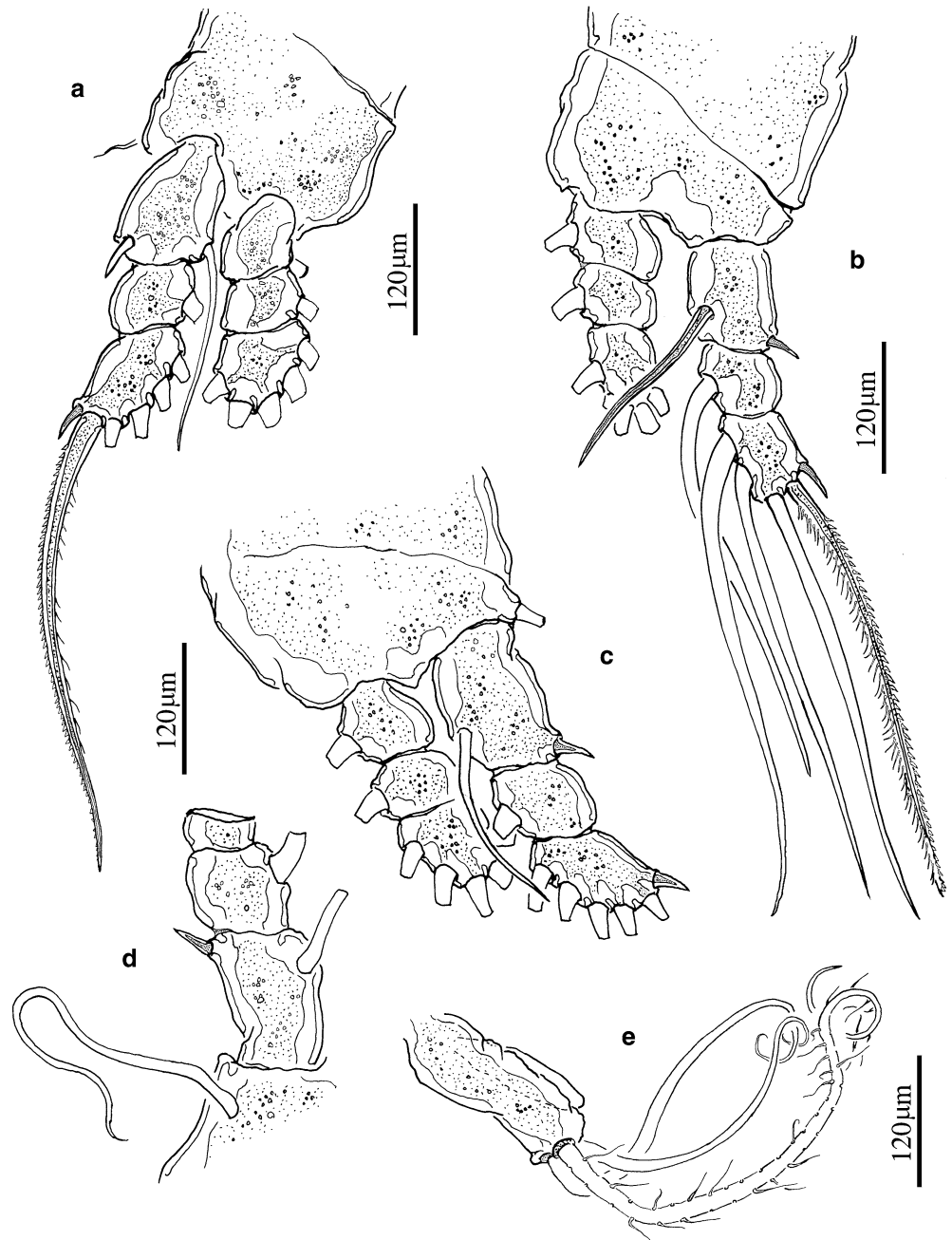
Remarks

The specimen was extremely fragile but almost complete, only some setae and part of the third swimming legs were missing. Thus, considering the long time of preservation (over 110 years), it was in a surprisingly good condition for taxonomical examination.

Discussion

This species was described by R. Timm in 1896. However, a preliminary notice in which the name was

Fig. 3 *Cymbasoma germanicum* (Timm). Adult female from Helgoland. **a** Left fourth swimming leg, *anterior view*; **b** right first swimming leg showing stout seta on first exopodal segment, *anterior view*; **c** right second swimming leg, *anterior view*; **d** proximal segments of exopod of third swimming leg, with basipodal seta; **e** fifth legs showing position and length of setae on outer lobe

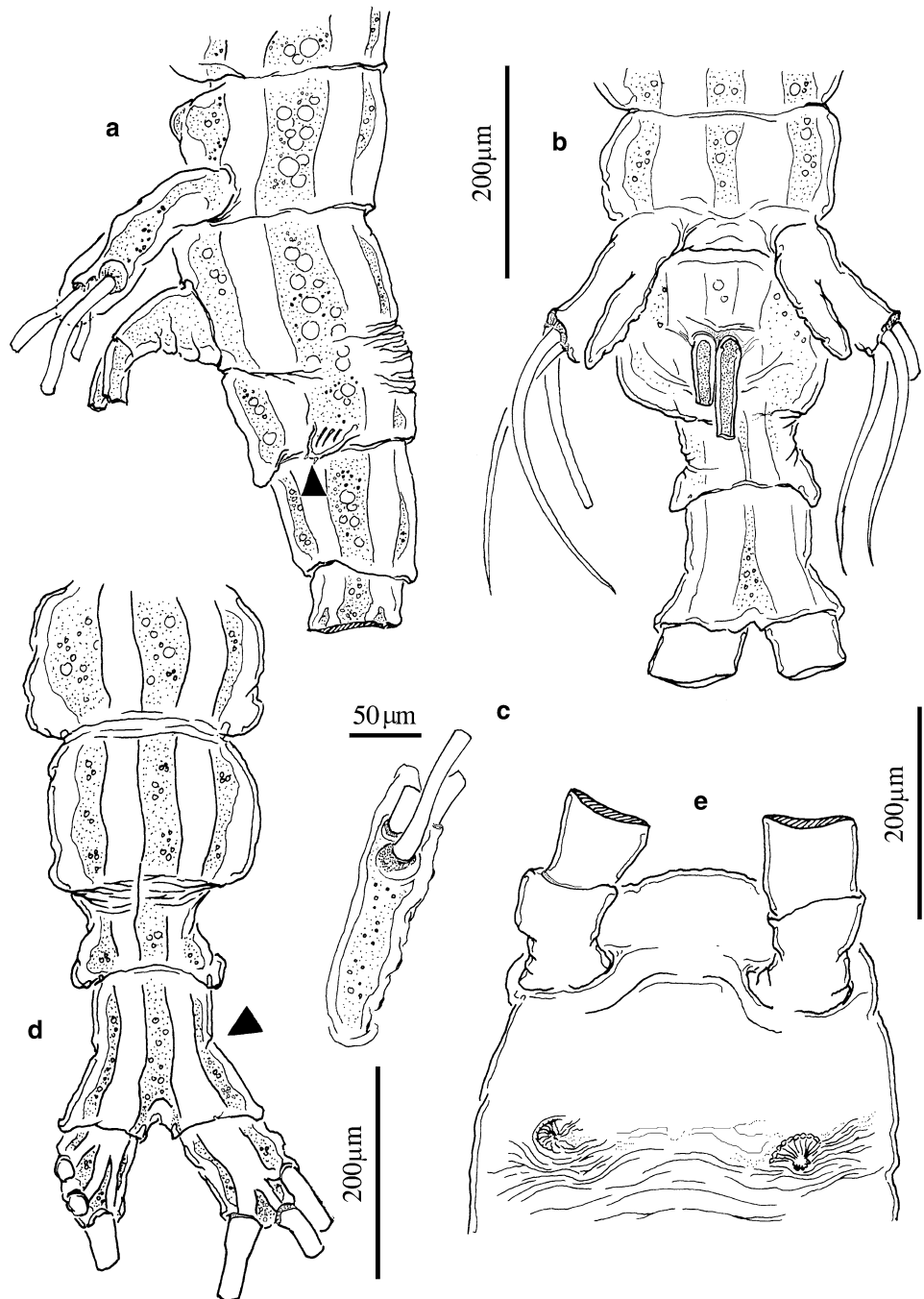


included as part of an identification key (Timm 1893), made this name available earlier than the description proper. Unfortunately, the author did not explicitly designate or deposit type specimens, thus they were initially considered unavailable. It is not known if R. Timm identified this specimen himself; however, it is likely that he did as this material was collected in Helgoland in 1892, a period in which he was actively working on the area. Furthermore, Timm's description of this species was based on the observation of several specimens (see Timm 1896): three from the Helgoland area (Cuxhaven) that were collected in 30 September 1890, several other specimens found at Helgoland during 1893, plus one from a plankton sample collected on the

Doggerbank, this one without information on the date of collection. It is clear that the original syntypic series was collected at Helgoland between 1890 and 1893. Therefore, it is likely that the specimen examined herein was identified by R. Timm himself; there is also reasonable evidence to assume that this specimen could be part of the original syntypic series.

After the publication of this species, the name was used by several authors (Malaquin 1901; Nordgaard 1901), but it was soon synonymized, among others, by Sars (1921) mentioning that he was unable to find any reliable character to distinguish this species and other related forms and thus suggested regrouping them as a single species using the oldest name, *rigidus*.

Fig. 4 *Cymbasoma germanicum* (Timm). Adult female from Helgoland. **a** Habitus, lateral view; **a** urosome, left lateral view showing lateral process (arrowed) and dorsal striae; **b** urosome and fifth legs, ventral view; **c** fifth legs, lateral view; **d** urosome, dorsal view showing notch on margins of anal somite; **e** anterior end of cephalothorax showing nipple-like structures, ventral view



The specimen examined herein has the same general characters than those presented in the original description of *C. germanicum* by Timm (see Table 1) and there is no doubt that this specimen belongs to the same species, *C. germanicum* if not part of the original syntypic series. The similarities include also the size [3 mm in Timm (1896), 2.9 mm in the specimen examined], the position of the oral papilla, the length of the ovigerous spines, and the proportions of the body and the antennular segments.

It is clear that *C. germanicum* is very closely related to *C. rigidum*, but Timm (1896) did not include *C. rigidum*

in his key to the species of *Cymbasoma*. He distinguished it from both *Cymbasoma thompsoni* Giesbrecht 1892 and *Cymbasoma claparedii* Giesbrecht 1892, the latter mentioned as a synonym of *C. rigidum* (Sars 1921). He based this key on the structure and relative size of the inner lobe and the length of the inner seta of the outer lobe of the fifth legs. If the widely used regional key for the identification of the Eastern Atlantic Monstrilloidea published by Isaac (1975) is followed, this specimen, with a suture or notch on the outer margin of the anal somite, keys down to a couplet in which *C. rigidum* and *Cymbasoma zetlandicus* are

Table 1 Comparative analysis of characters used in the identification of *Cymbasoma rigidum* and related forms

	Sars (1921) Norway	Timm (1896) Helgoland	Bernier et al. (2002) Canada	Thompson (1888) Canary Is.	Bourne (1890) England	Sekiguchi (1982) Japan	Scott (1904) Scotland	Giesbrecht (1892) Naples	Wilson (1932) Woods Hole	Suarez (this work) Helgoland
Length of P5OL/P5IL	3.25	1.8	17.5	No inner lobe described	1.4	3.1	10	?	2.6	1.6
GS/AS	1.36	2	1.47	1.57?	1.5	1.6	1.25	1.6	1.4	2 ^a
OVS/TL	0.34	?	0.48	0.35?	? "Not far beyond furcal setae"	0.27	0.38	0.54	–	0.42
ISOL-P5 smaller than other P5S?	Yes	No	Yes	Yes?	No	Yes	No	No	Yes	No
ISOL-P5/MSOLP5	0.52	0.88	0.51	?	0.87	0.23	0.96	0.99	0.33	0.99
LAI/TL	0.166	0.17	0.160	0.28	?	?	0.15	0.18	0.15	0.14
Elements 2v, 2d of AI.	Short	Long	Long	?	?	Short	Short	Short	Short	Long ^a
Notch on outer margin of AS	Present	Present	Present	?	Undefined	Undefined	Present	Present	Present	Present
Lateral process on GS	Absent	Not evident	Absent	?	Absent	Absent	Absent	Absent	Absent	Present ^a

Elements 2v and 2d from Grygier and Ohtsuka's (1995) nomenclature of setal armature of female monstrilloid copepods P5 fifth legs, OL outer lobe, IL inner lobe, GS genital double somite, AS anal somite, ISOL inner seta of outer lobe, MSOL middle seta of outer lobe, LAI length of antennule, TL total length^aMain differences of *C. germanicum*

separated. This couplet distinguishes these two species mainly by the relative length of the genital double somite: as long as the rest of the urosome in the latter, and shorter than the urosome in the former. In *C. germanicum* the genital double somite is larger than the rest of the urosome. Also, the proximal half of the genital double somite is globose in *C. germanicum*, versus a moderately swollen condition shown by other records of *C. rigidum* (Scott 1904; Sars 1921; Sekiguchi 1982).

Timm's drawing of the habitus in ventral view (Pl. V, Fig. 3) is the only depicted reference on the proportion and probable armature of the antennule of the specimens of *C. germanicum* examined by him (i.e. presumed type specimens). This figure, although illustrated on a small scale, shows some setal pairs, which seem to be correctly arranged and some can be identified in terms of Grygier and Ohtsuka's (1995) antennular armature pattern. This is useful to complete the description because some of the setae are lost in the specimen examined herein and can be accounted from Timm's illustration. The proportion of the four segments is very much in accordance with that of this specimen. The presence and approximate size of some of the missing setae can be identified on the second segment, in which elements 2v_{1,3} are clearly long, well developed; this is a character not shared by most other illustrated records of *C. rigidum* (see Table 1) and it is present in *C. germanicum*. It is added to the set of characters useful in separating this species. Timm's illustration shows the complete set of setal elements of the third segment (3, IIIv, III d) and some of the fourth (IVv, IVd, 4v₂₋₃, Vv, Vd, b₁₋₅). The terminal elements 6₁ and 6₂ are shown in this figure, and are absent (broken off) in my specimen. The large ventral aesthetasc (4aes) on the fourth segment, the small terminal one (6aes), and elements 2d₁₋₂ and 4d₁₋₂ were not depicted by Timm (1896).

The swimming legs were described by Timm (1896), but only legs 1 and 3 were illustrated. He reported a specimen with an abnormal pattern of five setae on the third exopodal segment of the first leg, which has typically four setae in the Monstrilloida. The legs 1–4 show the usual pattern of armature and setation known for monstrilloids; hence, the basipodal external setae of swimming legs are present in this species although lost in legs 1 and 2 in the specimen examined. An interesting character found in the first swimming leg of the specimen reported herein is the structure of the inner spine on the first exopod. It is noticeably thicker and stiffer than in the other legs.

The combination of characters on the fifth legs, body proportions, and antennule length and ornamentation would seem enough to separate this species from other members of the genus. However, the main distinguishing character of *C. germanicum* is the presence of the two knob-like postero-lateral processes on the genital double somite; no similar structure has been reported in any other monstrilloid of this genus.

Cymbasoma rigidum, a species complex?

One of the most representative cases of a taxonomically conflictive nominal species is represented by *Cymbasoma rigidum*, a species described by Isaac C. Thompson (1888) from samples collected off the Canary Islands. The description is too shallow to determine the specific characters, and the drawings offer little information. The poor definition of the species, which is also the type species of the genus (Grygier 1995), generated successive records of the nominal species in different parts of Europe and later on also in the Americas, most of them carefully documented by Grygier (1995). Several closely related species were described and some of them were synonymized at different times with *C. rigidum*, including *C. germanicum*, *C. thompsonii* Giesbrecht 1892, *C. claparedii* Giesbrecht 1892 (see Giesbrecht 1892; Scott 1904; Sars 1921; Isaac 1974). Quite surprisingly, aside the original description, which was based on one female specimen only, there are no other records of this species from the area of the type locality in more than 115 years. There is no evidence that any of the authors that recorded this species had access to this single original specimen.

The morphology of the fifth legs is one of the most important features used in the taxonomical identification and characterization of monstrilloid copepods. An analysis of the structural patterns of the fifth legs of *C. rigidum* that were reported and depicted in the literature between 1890 and 2002 is presented in Fig. 5. There are strong variations in this appendage; the main ones were found on the length and development of the inner lobe. This structure can be very long, reaching the distal end of the outer lobe as in *C. rigidum* (recorded as *Monstrilla rigidum*) from Plymouth and Channel Islands, England (Bourne 1890), in specimens reported by Wilson (1932) from Woods Hole, and by Sars (1921) from Norway (see Fig. 5a, c, e). Another pattern is shown by an extremely short, weakly developed inner lobe, as in records of this species by Scott (1904) from Scotland or quite recently by Bernier et al. (2002) from the Gulf of St. Lawrence, Canada (Fig. 5d, f). An intermediate pattern was reported by Sekiguchi (1982) from Ago Bay, Japan (Fig. 5g). It is noted here that the size and shape of the inner lobe has been used recently to separate species in other species complexes, mainly in *Cymbasoma longispinosum* (see Grygier 1994b; Suárez-Morales and Escamilla 1997; Suárez-Morales and Palomares 1997). Another variable character of the fifth legs is the relative length of the inner terminal seta of the outer lobe; it can be nearly as long as the other setae, as in *C. germanicum* (Timm 1896), and in reports of *C. rigidum* by Bourne (1890), and Scott (1904). A short inner seta, about half the length of the other two setae, is present in the specimens reported by Sars (1921), Wilson (1932), Sekiguchi (1982), and Bernier et al. (2002). It seems unlikely that all these mixed patterns can be reliably associated to a single species.

It is speculated here that the original uncertainty associated with the definition of *C. rigidum* was the

starting point of most of the current taxonomical problems related to this nominal species. It is necessary to obtain and analyze specimens from the type locality (Madeiras, Canary Islands) in order to establish a neotype of *C. rigidum*. It is intriguing also that neither the original description nor the accompanying illustrations give any data about this species having a fifth leg with an inner lobe. Thompson's (1888) description mentions that the fifth legs are composed "...of a long joint, at the apex of which are three strong spinous setae". This suggests also that in this original specimen the three setae are equal or subequal in length and width and that they are stout, a character not shown or remarked in any other depiction of the fifth leg setae, which were all illustrated as flexible, not spinous.

The antennules shown in the figure of the habitus (Thompson 1888, pl. XIII, Fig. 1) are relatively longer (27% of the total length) than in any other depiction of *C. rigidum* in the literature (0.14–0.18; see Table 1). The first good illustrations of *Cymbasoma rigidum* (as *Monstrilla rigidum*) were those published by Bourne (1890) from specimens collected in Jersey and Plymouth, England. Bourne's interpretation of *C. rigidum* was taken by Scott (1904), who included this species under *Thaumaleus*, and later on by Sars (1921), who also provided good illustrations of this nominal species and disregarded the differences of the fifth legs shown in previous reports. These early works defined the profile of

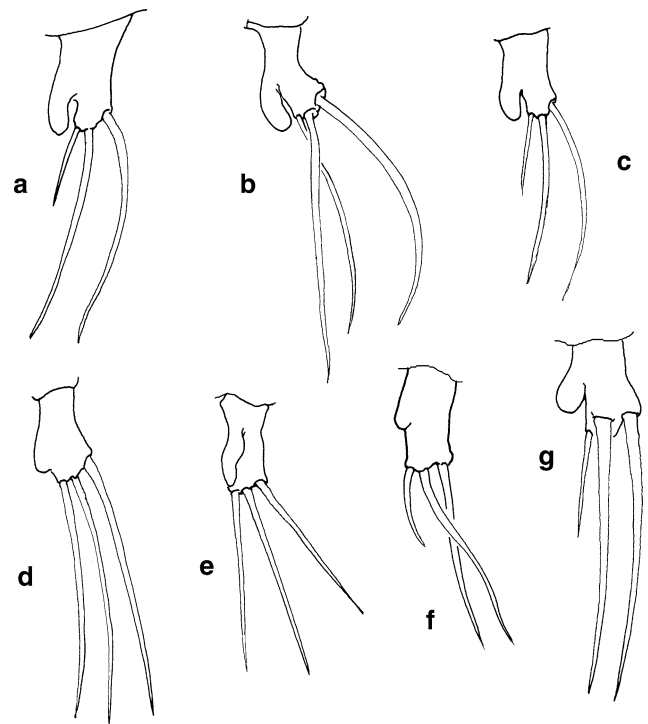


Fig. 5 Structure of different morphological types of fifth legs historically related to the nominal *Cymbasoma rigidum* and related forms. **a** Wilson (1932) from Woods Hole; **b** *Cymbasoma germanicum* (Timm 1896); **c** Sars (1921) from Norway; **d** Scott (1904) from Scotland; **e** Bourne (1890) from England; **f** Bernier et al. (2002) from Canada; **g** Sekiguchi (1982) from central Japan

what is currently known as *C. rigidum*, but not necessarily of the specimen from Madeira studied by Thompson. Therefore, it is speculated that the original description of *C. rigidum* corresponds to another species, possibly already described; it has characters similar to *Cymbasoma reticulatus* Giesbrecht 1892 and/or *Cymbasoma quintanarooense* (Suárez-Morales 1994). In this case, all the known records of *C. rigidum* would have to be assigned to one or more different species.

On the other hand, and based on the strong morphological variation of the nominal species, and on its improbable cosmopolitan geographical range, it is likely that the nominal *C. rigidum* represents a complex of species with different morphotypes.

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