Development of an interactive identification key for Oncaeidae (Copepoda: Cyclopoida)

Ruth Böttger-Schnack*a and Dietrich Schnackb

aDZMB-Senckenberg, German Centre for Marine Biodiversity Research, Hamburg, Germany; bGEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany

(Received 13 September 2014; accepted 4 February 2015; first published online 29 June 2015)

The current state of development of an interactive electronic identification key for females of the marine pelagic microcopepod family Oncaeidae is presented. To date, 112 species have been described, allocated to seven genera (Archioncaea, Conaea, Epicalymma, Monothula, Oncaea s.str., Spinoncaea, and Triconia) and 16 species groups within the speciose paraphyletic taxon Oncaea s.l. Only two species of Oncaea s.l. show an uncertain group status. Of all described oncaeids, seven species are not yet included in the key due to inadequacies in morphological description and/or lack of type material for re-examination. In addition, seven morphologically distinct species and two new species groups are considered that have not yet been formally described. The key uses easily distinguishable morphological characters as far as possible (e.g. body size, proportional lengths of urosomites, length of P5 exopod) and includes more difficult characters (e.g. spine counts on swimming legs, proportional spine lengths) where required for unequivocal identification. The characters used in the key allow the identification of genera and species groups by investigators with limited taxonomic experience; species separation in most cases requires some advanced dissection skills. Potential identification problems caused by difficulties discerning minute morphological features or intraspecific morphometric variability are discussed. The present version of the identification key still requires complementary illustrations of character states and inclusion of fact sheets summarizing the characteristics of each species with notes on taxonomic uncertainties and links to databases providing zoogeographical and genetic information.

Keywords: taxonomy; Oncaeidae; identification; key

Introduction

The microcopepod family Oncaeidae is one of the most abundant copepod taxa in marine pelagic habitats. It occurs in all climates from tropical to polar seas and in all vertical layers from the surface to the deep sea (e.g. Nishibe 2005 and literature cited therein; Koppelmann et al. 2009; Kosobokova et al. 2011; McKinnon et al. 2013). The family is very diverse, with more than 100 species described to date (Böttger-Schnack and Boxshall 2014). Most of them are smaller than 600 µm in size as adults and are thus challenging to adequately consider in studies on species diversity. The role of oncaeid species in the marine pelagic environment is also largely unknown (reviewed by Böttger-Schnack et al. 2004), because studies on their species specific...
requirements are hampered by identification problems in part caused by their small size. Over the past three decades, oncaeid morphology has been studied in great detail. The mouthparts, in particular, are now known much better and have provided an important basis for the definition of genera and species groups (Böttger-Schnack and Huys 1998; Böttger-Schnack and Schnack 2013). The number of described oncaeid species has significantly increased, and genetic studies using barcoding have proven the importance of minor morphological details for separating sibling species (Böttger-Schnack and Machida 2011). Published identification keys for Oncaeidae in the printed literature are all regionally limited: they often do not include the many small-sized species less than 500 µm, and do not include recent taxonomic progress (e.g. Shmeleva 1969; Heron 1977; Heron et al. 1984; Bradford-Grieve et al. 1999). The few available regional online keys are of restricted use because they do not include all species known for the region (e.g. Marine Species Identification Portal 2014, http://species-identification.org; Zooplankton Identification Manual for North European Waters 2014, http://192.171.193.133) and/or are in part erroneous (e.g. Swadling et al. 2013 (ed.) Australian Marine Zooplankton, http://www.imas.utas.edu.au).

At present, the generic system of Oncaeidae is only partly resolved. This represents a fundamental problem for the development of a general identification key. So far, seven genera are recognized (Boxshall and Halsey 2004): Archioncaea Böttger-Schnack and Huys, 1997; Conaea Giesbrecht, 1891; Epicalymma Heron, 1977; Monothula Böttger-Schnack and Huys, 2001; Oncaea Philippi, 1843; Spinoncaea Böttger-Schnack, 2003 and Triconia Böttger-Schnack, 1999. The large genus Oncaea is a paraphyletic taxon (Böttger-Schnack and Huys 1998) that comprises still another 17 morphologically distinct lineages. One of these includes the type species of the family, Oncaea venusta Philippi, and has been formally separated as Oncaea sensu stricto (Böttger-Schnack 2001). All other lineages of Oncaea sensu lato will be called ‘species groups’ or ‘groups’ hereafter (cf. Böttger-Schnack and Schnack 2013, table 1). The identification of oncaeid genera and groups is difficult because the characters used to define them are mainly based on details of the mouthparts (cf. Böttger-Schnack and Schnack 2013, tables 2 and 3). Observation of mouthparts in microcopepods requires a high level of dissection skill and therefore these characters were not considered practical for non-specialists. Instead, characters had to be found that are easier to discern or recognize.

The aim of this key is to facilitate the identification of species and genera or species groups from throughout the global ocean and to primarily use easily accessible characters. In cases where practical species determination is difficult or distinctions are not yet fully resolved, the key should nevertheless allow the identification of genera or species groups.

**Methodological background of the key**

The key is built on Lucid 3.5 software, developed for the construction of identification keys at the University of Queensland, Australia, and now distributed by the company Identic Pty Ltd. (www.lucidcentral.org). At present, a total of 112 oncaeid species are considered in this key; additional species can be easily included when new descriptions are provided. Of the valid species described in the literature to date (Böttger-Schnack and Boxshall 2014), seven species have not been included because
the descriptions are not sufficiently clear and require revision (cf. Böttger-Schnack and Schnack 2013, table 3B). In addition, seven yet undescribed species from the personal copepod collection of the first author have been included, each of which show distinct characters and can be clearly separated from all other known species (cf. Böttger-Schnack and Schnack 2013, table 3C). Within the key, genera and species groups are listed in alphabetical order, as are the species within their respective genus or group. Those species which could not yet be allocated to groups are presented at the beginning, and the new, as yet undescribed species at the end of the list.

The morphological data used in this key are taken from reliable taxonomic publications (for references see Appendix Table A1) and for about half of the species personal descriptions, unpublished observations and line drawings from the first author are used. Discrete characters such as numbers of spines on the legs are generally preferred because they can be clearly defined, but continuous characters such as body length and size ratios of body parts had to be used as well, though these can be less clearly defined. Primary characters have been considered for all species in the family, whereas secondary characters are considered only for selected species or groups as required. Within the key, morphological features are arranged from the anterior to the posterior end of the body. Figure 1 shows the Lucid identification screen, with features presented in the top left window, and the copepod taxa (called ‘entities’) in the top right window. Features and entities (taxa) are organized in several levels of subgrouping and presented as trees, which can be expanded or collapsed as required.

Descriptive terminology follows that of Huys and Boxshall (1991), and the abbreviations P1–P5 are used to represent the first to fifth thoracopods.

**Development of key matrix**

The primary characters considered for identification are presented in Table 1, grouped according to the skill required for their observation. For some characters the determination is easy because no or only simple dissection is required, but others require more advanced dissection skills and are thus more difficult to consider. Total length, length proportions of urosomites and the shape of the maxilliped basis are examples of easy characters. The number of spines on the swimming legs is more difficult to observe, but is of high diagnostic value. The combination of spine counts on the exo- and endopods of P1–P4 can be grouped into 14 different armature types (Figure 2), most of which represent a single genus, group or even species (cf. Böttger-Schnack and Schnack 2013, tables 5 and 6) and can be used for identification. However, one armature type is shared by a large number of different genera and groups (cf. Böttger-Schnack and Schnack 2013, table 4), and for these taxa other features had to be found.

[Note: In table 5 of Böttger-Schnack and Schnack (2013), the presentation of leg armature type 9 is missing erroneously; it refers to a new and yet undescribed morphospecies, *Oncaea* sp. K from Australian waters, which showed deviation from the typical oncaeid spine count on the endo- and exopods. Leg armature type 9 is given in Appendix Table A2.]
Among the primary characters, a small subset of preview features has been defined (marked in bold in Table 1), which are typical of individual species or groups. These preview features include body length, because size alone will considerably narrow down the number of species to be further considered (Figure 3). The cephalosome may have a very group specific shape (Figure 4) and the somite carrying P1 or P2 may have a characteristic dorsal protrusion or projection (Figure 5). The size of P5 exopod segment (Figure 6), the shape of the maxilliped basis (Figure 7), and the presence or absence of a conical process between the two distal spines of P4 endopod (Figure 8) in addition to the corresponding process on P2 and P3, are easily

Figure 1. Screen shot of the Lucid identification key for Oncaeidae, with morphological characters ('features') presented in the top left window, and the copepod taxa (called 'entities') in the top right window. Features and entities (taxa) are organized in several levels of subgrouping and presented as trees, which are partly expanded.
discernible features indicative of specific genera and groups or even species. In several cases some additional, secondary characters are required for a final identification of species (Table 2). For example, the length to width ratio of the caudal ramus can be used to separate species within the genus *Oncaea s. str.* or the length of the outer basal seta on P5 can separate the five described species belonging to the *dentipes*-subgroup of *Triconia*.

### Discussion

With the use of the characters outlined in this contribution, oncaeid specimens can be allocated to genera or species groups independent of any remaining identification problems. Within genera and groups species separation is possible in most cases, with the exception of *Epicalymma* species, or the many undescribed species in the *Oncaea atlantica-vodjanitskii*-group (cf. Böttger-Schnack et al. 2004, table 1B) and the
Triconia similis-subgroup (cf. Böttger-Schnack and Schnack 2009, table 3). For the latter, more advanced taxonomic descriptions are required, and that – once complete – may require some modification of the feature set.
Figure 4. Characteristics of cephalosome shape in oncaeid species. (A) Lateral view of species \textit{(Oncaea longipes} [from Kršinić and Malt 1985]) and front sections of cephalosome (original) undescribed morphospecies of \textit{longipes}-group, cf. Böttger-Schnack 1994, table 2) showing distal spinous process; (B) and (C) dorsal view of species showing bilateral protrusion of cephalosome (arrowed) at posterior margin \textit{(O. minima} [from Kršinić and Malt 1985]) or at midregion \textit{(O. vodjanitskii} [G.A. Boxshall, pers. comm.]).

Figure 5. Characteristics of P1- or P2-bearing somite in oncaeid species. (A) P1-bearing somite with dorsal protrusion ([original] undescribed morphospecies \textit{Oncaea} sp. 4.2, cf. Böttger-Schnack and Schnack 2013, table 3); (B) and (C) P2-bearing somite with dorsal projection or swelling: (B) \textit{Triconia conifera} [from Böttger-Schnack 1999]; (C) \textit{T. rufa} [from Böttger-Schnack 1999].
Figure 6. Characteristics of P5 in oncaeid species. Different types of length to width ratio of P5 exopod segment (blue), number of exopodal setae (green) and length of outer basal seta (red). (A) *Oncaea serrata* (notopus-group) [from Böttger-Schnack 2011]; (B) *Triconia similis* [from Böttger-Schnack 1999]; (C) *Spinoncaea humesi* [from Böttger-Schnack 2003].

Figure 7. Form types of maxilliped basis (shaded) in oncaeid species: compact (*Oncaea compacta* [from Heron 1977]); robust-oblong (*O. venusta f. typica* [from Böttger-Schnack 2001]); elongate (*O. bispinosa* [from Böttger-Schnack 2002]); very long and narrow (*O. tenuimana* [original]).
The usefulness of the key may be hampered by problems of observation: e.g. it might be difficult to count the endopodal spines when they are very small. However, possible misinterpretations of feature states are accommodated in the key. Some problems may also be encountered when measuring continuous characters such as the spine lengths on the endopods. Besides difficulty making a correct measurement of spines in a three-dimensional space under the microscope, the intraspecific variability of a certain spine length is not well known (Cho et al. 2013). Thus, at present, fairly wide ranges of possible values have been defined for these features. Another problem for identification keys in general is the morphological uncertainty of species, particularly those that have not been described in sufficient detail or that are new to science. The validity of species names also has to be taken in mind (e.g. Böttger-Schnack and Huys 2004). Finally, it remains uncertain whether species descriptions for particular regions can be transferred to other areas of the world ocean. There may be slight differences between populations of the same species, or sibling species, which have developed in different areas (e.g. Ueda and Bucklin 2006; Sakaguchi and Ueda 2010; Böttger-Schnack 2011; Ueda et al. 2011) and that at first sight look morphologically very much alike.
It is urgently recommended to use a genus, group- or subgroup-name in cases where species identification remains uncertain. Presenting uncertain species names will lead, and has already led, to erroneous information about zoogeographic distribution patterns, e.g. the distribution pattern reported for the well-known species *Triconia conifera* (Giesbrecht, 1891) (Razouls et al. 2005–2014a), which actually represents a subgroup of 13 closely related species (Wi et al. 2012) each with a different distribution pattern, e.g. *T. antarctica* (Heron, 1977) or *T. derivata* (Heron and Bradford-Grieve, 1995) (Razouls et al. 2005–2014b, 2005–2014c). Identification keys using relational databases, such as the Lucid 3 program, avoids the need to review states of features in a fixed sequence, but rather allows the consideration of features according to their accessibility, so that even damaged specimens or parts of specimens may lead to successful identification. The system also allows an easy addition of new species and updating as improved taxonomic knowledge becomes available. The software itself supports the identification process by providing suggestions for the best or next best feature to look at for a quick identification by eliminating features no longer relevant, and by providing a list of differences relevant for the separation of remaining species. The final key will have to include illustrations for all feature states considered and ‘fact sheets’ summarizing the characteristics of each species, including notes on controversial taxonomic issues of the respective taxon and links to databases providing species specific zoogeographical and

Table 2. Secondary morphological characters used for identification key of oncaeid copepods, grouped according to dissection skills required for observation. These characters are considered only for selected species, genera or groups, as required for final separation. For abbreviations see Table 1.

| Body parts       | No dissection | Simple dissection | Difficult dissection |
|------------------|---------------|-------------------|----------------------|
| Cephalosome      | Shape of front part | Size of dorsal projection | Pleural plate |
| P2-bearing somite| Size of dorsal projection | Pleural plate | Length and form of setae |
| P5-bearing somite| General shape, position of genital apertures | Pleural plate | Fusion of exopod, length of outer basal seta |
| P5 exopod        | General shape, position of genital apertures | Pleural plate | Length/width ratio |
| Genital double-somite | General shape, position of genital apertures | Pleural plate | Distal and proximal element (length ratio, form, ornamentation) |
| Caudal ramus     | Length/width ratio | Distal and proximal element (length ratio, form, ornamentation) | Length and form of elements |
| Maxilliped basis | Distal and proximal element (length ratio, form, ornamentation) | Distal and proximal element (length ratio, form, ornamentation) | Segment form, conical process form, length ratio of spines |
| Antenna (distal endopod segment) | Distal and proximal element (length ratio, form, ornamentation) | Distal and proximal element (length ratio, form, ornamentation) | Length of spines |
| P2–P4 endopod    | Distal and proximal element (length ratio, form, ornamentation) | Distal and proximal element (length ratio, form, ornamentation) | Length of spines |
| P3 and P4 exopod | Distal and proximal element (length ratio, form, ornamentation) | Distal and proximal element (length ratio, form, ornamentation) | Length of spines |
genetic information [e.g. World Register of Marine Species WoRMS (http://www.marinespecies.org), Marine Planktonic Copepods (http://copepodes.obs-banyuls.fr/en) and Genbank (http://www.ncbi.nlm.nih.gov/genbank/)]. After completion, the key will be made available for general use and will be announced on the web site of the first author (http://rb-schnack.de)

Acknowledgements
We wish to thank Prof. Dr. P. Martinez Arbizu (Senckenberg Research Institute, German Centre for Marine Biodiversity Research, Wilhelmshaven) for organizational help. The valuable comments of two referees are gratefully acknowledged. The study was supported by a research grant from the German Science Foundation to RBS [Schn 455/6-1].

Disclosure statement
No potential conflict of interest was reported by the author(s).

References
Böttger-Schnack R. 1994. The microcopepod fauna in the Eastern Mediterranean and Arabian Seas: a comparison with the Red Sea fauna. Hydrobiologia. 292–293:271–282.
Böttger-Schnack R. 1999. Taxonomy of Oncaeidae (Copepoda, Poecilostomatoida) from the Red Sea. - I. 11 species of Triconia gen. nov. and a redescription of T. similis (Sars) from Norwegian waters. Mitt Hamb Zool Mus Inst. 96:37–128.
Böttger-Schnack R. 2001. Taxonomy of Oncaeidae (Copepoda: Poecilostomatoida) from the Red Sea. II. Seven species of Oncaea s. str. Bull Nat Hist Mus London (Zool). 67:25–84.
Böttger-Schnack R. 2002. Taxonomy of Oncaeidae (Copepoda, Poecilostomatoida) from the Red Sea. VI. Morphology and zoogeography of Oncaea bispinosa sp. nov., a sister taxon of O. zernovi Shmeleva. J Plankton Res. 24:1107–1129.
Böttger-Schnack R. 2003. Taxonomy of Oncaeidae (Copepoda, Poecilostomatoida) from the Red Sea. V. Three species of Spinoncaea gen. nov. (ivlevi-group), with notes on zoogeographical distribution. Zool J Linn Soc. 137:187–226.
Böttger-Schnack R. 2011. Taxonomic re-examination and distribution of copepods reported as Oncaea notopus Giesbrecht, 1891 (Copepoda, Oncaedae) in the Mediterranean Sea. Mar Biodiv. 41:325–341.
Böttger-Schnack R, Boxshall G. 2014. Oncaeidae Giesbrecht, 1893 [“1892”]. In: Walter TC, Boxshall G editors. [cited 2014 Aug 22]. World of Copepods database [internet]. Accessed through: World Register of Marine Species at http://www.marinespecies.org/aphia.php?p=taxdetails&id=128586
Böttger-Schnack R, Huys R. 1997. Archioncaea arabica gen. et sp. nov., a remarkable oncaeid (Copepoda: Poecilostomatoida) from the northern Arabian Sea. Cah Biol Mar. 38:79–89.
Böttger-Schnack R, Huys R. 1998. Species groups within the genus Oncaea Philippi, 1843 (Copepoda, Poecilostomatoida). J Mar Syst. 15:369–371.
Böttger-Schnack R, Huys R. 2001. Taxonomy of Oncaeidae (Copepoda, Poecilostomatoida) from the Red Sea. III. Morphology and phylogenetic position of Oncaea subtilis Giesbrecht, 1892. Hydrobiologia. 453/454:467–481.
Böttger-Schnack R, Huys R. 2004. Size polymorphism in Oncaea venusta Philippi, 1843 and the validity of O. frosti Heron, 2002: a commentary. Hydrobiologia. 513:1–5.
Böttger-Schnack R, Lenz J, Weikert H. 2004. Are taxonomic details of relevance to ecologists? An example from oncaeid microcopepods of the Red Sea. Mar Biol. 144:1127–1140.
Böttger-Schnack R, Machida RJ. 2011. Comparison of morphological and molecular traits for species identification and taxonomic grouping of oncaeid copepods. Hydrobiologia. 666:111–125.

Böttger-Schnack R, Schnack D. 2009. Taxonomic diversity and identification problems of oncaeid microcopepods in the Mediterranean Sea. Mar Biodiv. 39:131–145.

Böttger-Schnack R, Schnack D. 2013. Definition of species groups of Oncaeidae (Copepoda: Cyclopoida) as basis for a worldwide identification key. J Nat Hist. 47:265–288.

Boxshall GA, Böttger R. 1987. Two new species of *Oncaea* (Copepoda: Poecilostomatoida) from the Red Sea and a redescription of *O. atlantica* Shmeleva. J Plankton Res. 9:553–564.

Boxshall GA, Halsey SH. 2004. An introduction to copepod diversity. London: Ray Society; 421 pp.

Bradford-Grieve JM, Markhaseva EL, Rocha CEF, Abiahy B. 1999. Copepoda. In: Boltovskoy D, editor. South Atlantic Zooplankton. Vol. 2. Leiden: Backhuys Publishers; p. 869–1098.

Cho K, Kim W-S, Böttger-Schnack R, Lee W. 2013. A new species of the *dentipes*-subgroup of *Tricionia* and a redescription of *T. giesbrechti* and *T. elongata* (Copepoda: Cyclopoida: Oncaeidae) from the tropical Pacific and the Korea Strait. J Nat Hist. 47:1707–1743.

Giesbrecht W. 1891. Elenco dei Copepodi pelagici raccolti dal tenente di vascello Gaetano Chierchia durante il viaggio della R. Corvetta ‘Vettor Pisani’ negli anni 1882–1885, e dal tenente di vascello Francesco Orsini nel Mar Rosso, nel 1884. Atti Accad naz dei Lincei Rd. 7:474–481.

Heron GA. 1977. Twenty-six species of Oncaeidae (Copepoda: Cyclopoida) from the Southwest Pacific-Antarctic area. Biology of the Antarctic Seas VI. 26:37–96.

Heron GA, Bradford-Grieve JM. 1995. The marine fauna of New Zealand: pelagic Copepoda: Poecilostomatoida: Oncaeidae. NZ Oceanogr Inst Mem. 104:1–57.

Heron GA, English TS, Damkaer DM. 1984. Arctic Ocean Copepoda of the genera *Lubbockia*, *Oncaea* and *Epicalymma* (Poecilostomatoida: Oncaeidae), with remarks on distributions. J Crust Biol. 4:448–490.

Huys R, Boxshall GA. 1991. Copepod evolution. London: The Ray Society.

Koppelmann R, Böttger-Schnack R, Möbius J, Weikert H. 2009. Trophic relationships of zooplankton in the eastern Mediterranean based on stable isotope measurements. J Plankton Res. 31:669–686.

Kosobokova KN, Hopcroft RR, Hirche H-J. 2011. Patterns of zooplankton diversity through the depths of the Arctic’s central basins. Mar Biodiv. 41:29–50.

Kršinić F, Malt SJ. 1985. Little known species of small Oncaeidae (Cyclopoida) from the South Adriatic. J Plankton Res. 7:189–199.

Marine Species Identification Portal [Internet]. 2014. [cited 2014 Aug 25]. Available from: http://species-identification.org/species.php?species_group=Zsao&menuentry=plaatjessleutel&pagenum=1273;

McKinnon AD, Duggan S, Böttger-Schnack R, Gusmão LFM, O’Leary RA. 2013. Depth structuring of pelagic copepod biodiversity in waters adjacent to an Eastern Indian Ocean coral reef. J Nat Hist. 47:639–665.

Nishibe Y. 2005. The biology of oncaeid copepods (Poecilostomatoida) in the Oyashio region, western subarctic Pacific: its community structure, vertical distribution, life cycle and metabolism [PhD dissertation]. Hokkaido University.

Philippi A. 1843. Fernere Beobachtungen über die Copepoden des Mittelmeeres. Arch Naturgesch. 9:54–71.

Razouls C, de Bovée F, Kouwenberg J, Desreumaux N. 2005–2014a. Diversity and Geographic Distribution of Marine Planktonic Copepods [Internet]. *Triconia conifera* (Giesbrecht, 1891). [cited 2014 Sept 10]. Available from: http://copepodes.obs-banyuls.fr/en/fichesp.php?sp=2122
Razoul C, de Bovée F, Kouwenberg J, Desreumaux N. 2005–2014b. Diversity and Geographic Distribution of Marine Planktonic Copepods [Internet]. Triconia antarctica (Heron, 1977). [cited 2014 Sept 10]. Available from: http://copepodes.obs-banyuls.fr/en/fichesp.php?sp=2120

Razoul C, de Bovée F, Kouwenberg J, Desreumaux N. 2005–2014c. Diversity and Geographic Distribution of Marine Planktonic Copepods [Internet]. Triconia derivata (Heron & Bradford-Grieve, 1995). [cited 2014 Sept 10]. Available from: http://copepodes.obs-banyuls.fr/en/fichesp.php?sp=2124

Sakaguchi SO, Ueda H. 2010. A new species of Pseudodiaptomus (Copepoda: Calanoida) from Japan, with notes on the closely related P. inopinus Burckhardt, 1913 from Kyushu Island. Zootaxa. 2623:52–68.

Shmeleva AA. 1969. Espèces nouvelles du genre Oncaea (Copepoda, Cyclopoida) de la mer Adriatique. Bull Inst Océanogr Monaco. 68:1–28.

Swadling KM, Slotwinski A, Davies C, Beard J, McKinnon AD, Coman F, Murphy N, Tonks M, Rochester W, Conway DVP, et al. 2013. Australian Marine Zooplankton: a taxonomic guide and atlas. Version 1.0 February 2013 [Internet] Available from: http://www.imas.utas.edu.au/zool plankton/image-key/copepoda/cyclopoida/oncaeidae

Ueda H, Bucklin A. 2006. Acartia (Odontacartia) ohtsukai, a new brackish-water calanoid copepod from Ariake Bay, Japan, with a redescription of the closely related A. pacifica from the Seto Inland Sea. Hydrobiologia. 560:77–91.

Ueda H, Yamaguchi A, Saitoh S-I, Sakaguchi SO, Tachihara K. 2011. Speciation of two salinity-associated size forms of Oithona dissimilis (Copepoda: Cyclopoida) in estuaries. J Nat Hist. 45:2069–2079.

Wi JH, Böttger-Schnack R, Soh HY. 2012. Two new species belonging to the dentipes- and conifera-subgroups of Triconia (Copepoda: Cyclopoida: Oncaeidae) from the East China Sea. J Crust Biol. 32:843–859.

Zooplankton Identification Manual for North European Waters [Internet]. 2014. [cited 2014 Aug 25]. Available from: http://192.171.193.133/taxnav.php?spname=Oncaeidae&dir=2;

Appendix

Table A1. List of references used for constructing the morphological data matrix of Oncaeidae species in the Lucid 3 program.

Böttger-Schnack R. 1999. Taxonomy of Oncaeidae (Copepoda, Plocilostomatoida) from the Red Sea. – I. 11 species of Triconia gen. nov. and a redescription of T. similis (Sars) from Norwegian waters. Mitt hamb zool Mus Inst. 96:37–128.

Böttger-Schnack R. 2001. Taxonomy of Oncaeidae (Copepoda: Poecilostomatoida) from the Red Sea. II. Seven species of Oncaea s. str. Bull Nat Hist Mus London (Zool). 67:25–84.

Böttger-Schnack R. 2002. Taxonomy of Oncaeidae (Copepoda, Plocilostomatoida) from the Red Sea. VI. Morphology and zoogeography of Oncaea bispinosa sp. nov., a sistertaxon of O. zernovi Shmeleva. J Plankton Res. 24:1107–1129.

Böttger-Schnack R. 2003. Taxonomy of Oncaeidae (Copepoda, Poecilostomatoida) from the Red Sea. V. Three species of Spinoncaea gen. nov. (ivlevi-group), with notes on zoogeographical distribution. Zool J Linn Soc. 137:187–226.

Böttger-Schnack R. 2004. Triconia parasimilis Böttger-Schnack, 1999 (Copepoda, Oncaeidae), first record from the NW Pacific (Oyashio), with the description of the male. Mitt hamb zool Mus Inst. 101:213–223.

Böttger-Schnack R. 2005. Taxonomy of Oncaeidae (Copepoda, Cyclopoida s.l.) from the Red Sea. VII. Oncaea cristata, a new species related to the ovalis-complex, and a revision of O. ovalis Shmeleva and O. bathyalis Shmeleva from the Mediterranean. Cah Biol Mar. 46:161–209.

(Continued)
Table A1. (Continued).

| Reference | Title | Pages |
|-----------|-------|-------|
| Böttger-Schnack R. 2009. | Taxonomy of Oncaeidae (Copepoda, Poecilostomatoida) from the Red Sea. – IX. Epicalymma bulbosa sp. nov., first record of the genus from the Red Sea. | J Plankton Res. 31:1027–1043. |
| Böttger-Schnack R. 2011. | Taxonomic re-examination and distribution of copepods reported as Oncaea notopus Giesbrecht, 1891 (Copepoda, Oncaeidae) in the Mediterranean Sea. | Mar. Biodiv. 41:325–341. |
| Böttger-Schnack R, Boxshall GA. 1990. | Two new Oncaea species (Copepoda: Poecilostomatoida) from the Red Sea. | J Plankton Res. 12:861–871. |
| Böttger-Schnack R, Huys R. 1997a. | Archioncaea arabica gen. et sp. nov., a remarkable oncaeid (Copepoda: Poecilostomatoida) from the northern Arabian Sea. | Cah Biol Mar. 38:79–89. |
| Böttger-Schnack R, Huys R. 1997b. | Morphological observations on Oncaea mediterranea (Claus, 1863) (Copepoda, Poecilostomatoida) with a comparison of Red Sea and eastern Mediterranean populations. | Bull nat Hist Mus Lond (Zool). 63:37–147. |
| Böttger-Schnack R, Huys R. 2001. | Taxonomy of Oncaeidae (Copepoda, Poecilostomatoida) from the Red Sea. III. Morphology and phylogenetic position of Oncaea subtilis Giesbrecht, 1892. | Hydrobiologia 453/454:467–481. |
| Boxshall GA. 1977. | The planktonic copepods of the northeastern Atlantic Ocean: Some taxonomic observations on the Oncaeidae (Cyclopoida). | Bull Br Mus Nat Hist Zool. 31:103–155. |
| Boxshall GA, Böttger R. 1987. | Two new species of Oncaea (Copepoda: Poecilostomatoida) from the Red Sea and a redescriptions of O. atlantica Shmeleva. | J Plankton Res. 9:553–564. |
| Cho K, Kim W-S, Böttger-Schnack R, Lee W. 2013. | A new species of the genus Oncaea (Cyclopoida) from the tropical Pacific and the Korea Strait. | J Nat Hist.47:1707–1743. |
| Giesbrecht W. 1893 ['1892']. | Systematik und Faunistik der pelagischen Copepoden des Golfes von Neapel und der angrenzenden Meeres-Abschnitte. | Fauna Flora Golf. Neapel 19:1–831, plates 1–54. |
| Giesbrecht W. 1902. | Copepoden. In: Expédition Antarctique Belge. Résultats du voyage du S.Y. Belgica en 1897–1898-1899. Rapp Scient Zool, Anvers:1–49, 13 pls. |
| Gordeyeva KT. 1972. | New species of the genus Oncaea (Copepoda, Cyclopoida) from the tropical zone of the Atlantic Ocean. | Zool Zh. 51:963–968. (in Russian, English summary) |
| Gordeyeva KT. 1973. | New species of the genus Oncaea (Cyclopoida) from the tropical Atlantic. | Zool Zh. 52:1572–1576. (in Russian, English summary) |
| Gordeyeva KT. 1975a. | Pelagic Cyclopoida (Copepoda) from the tropic Atlantic and the southern seas. | Zool Zh. 54:776–779. (in Russian, English summary) |
| Gordeyeva KT. 1975b. | A new species of the genus Oncaea (Copepoda) from the bathypelagial in the tropic zone of the Atlantic and Gulf of Mexico. | Zool Zh. 54:1397–1399. (in Russian, English summary) |
| Heron GA. 1977. | Twenty six species of Oncaecidae (Copepoda: Cyclopoida) from the Southwest Pacific Antarctic area. | In: Pawson L (ed) Biology of the Antarctic Seas, VI. Antarct Res Ser. 26:37–96. |
| Heron GA, Bradford-Grieve JM. 1995. | The marine fauna of New Zealand: Pelagic Copepoda: Poecilostomatoida: Oncaecidae. | NZ Oceanogr Inst Mem. 104:1–57. |
| Heron GA, English TS, Damkaer DM. 1984. | Arctic Ocean Copepoda of the genera Lubbockia, Oncaea, and Epicalymma (Poecilostomatoida: Oncaecidae), with remarks on distributions. | J Crust Biol. 4:448–490. |
| Heron GA, Frost BW. 2000. | Copepods of the family Oncaeidae (Crustacea: Poecilostomatoida) in the northeast Pacific Ocean and inland coastal waters of Washington State. | Proc Biol Soc Wash. 113:1015–1063. |

(Continued)
Table A1. (Continued).

Huys R, Böttger-Schnack R. (2008 [2007]) Taxonomy of Oncaeidae (Copepoda, Poecilostomatoida) from the Red Sea. – VIII. Morphology and phylogenetic position of *Oncaea tregoubovi* Shmeleva, 1968 and the closely related *Oncaea prendeli* Shmeleva, 1966 from the Mediterranean Sea. Mitt Hamb Zool Mus Inst. 104:89–127. (dated 2007)  
Kršinić F. 1988. Redescription of the female with a first description of the male of *Oncaea zernovi* Shmeleva (Copepoda: Poecilostomatoida). J Plankton Res. 10:543–553.  
Kršinić F, Malt SJ. 1985. Little known species of small Oncaeidae (Cyclopoida) from the South Adriatic. J Plankton Res. 7:189–199.  
Malt SJ. 1982. New and little known species of Oncaeidae (Cyclopoida) from the northeastern Atlantic. Bull Br Mus nat Hist. (Zool) 42:185–205.  
Sars GO. 1916. Liste systématique des Cyclopoidés, Harpacticoidés et Monstrilloïdés recueillis pendant les campagnes de S.A.S. le Prince Albert de Monaco, avec descriptions et figures des espèces nouvelles. Bull Inst océanogr Monaco 323:1–15, pls I-VIII.  
Shmeleva AA. 1968. New species of planktonic Copepoda: Cyclopoida from the Adriatic Sea. Zool Zh. 47:1784–1793. (in Russian, English summary)  
Shmeleva AA. 1979. New species and some previously unknown males of the genus *Oncaea* (Copepoda, Cyclopoida) from the Mediterranean. Zool Zh. 58:491–498. (in Russian, English summary)  
Shmeleva AA, Delalo EP. 1965. A new species of the genus *Oncaea* (Copepoda, Cyclopoida) from the Mediterranean Sea. Zool Zh. 44:1562–1565. (in Russian, English summary)  
Wi JH, Böttger-Schnack R, Soh HY. 2010. Species of *Triconia* of the *conifera*-subgroup (Copepoda, Oncaeidae) from Korean waters, including a new species. J Crust Biol. 30:673–691.  
Wi JH, Böttger-Schnack R, Soh HY. 2012. Two new species belonging to the *dentipes*- and *conifera*-subgroups of *Triconia* (Copepoda: Cyclopoida: Oncaeidae) from the East China Sea. J Crust Biol. 32:843–859.  
Wi JH, Shin K-S, Soh HY. 2011. The *similis*-subgroup within *Triconia* (Copepoda: Cyclopoida: Oncaeidae) from Korean waters (East China Sea), including a new species. Zool Stud. 50:588–604.  

Personal communication:  
Dr. Y. Nishibe, Atmosphere and Ocean Research Institute, University of Tokyo, Japan

Table A2: Leg armature type 9 of Oncaeidae: variation of spine count on endopod and exopod of Australian *Oncaea* sp. K (new morphospecies) with differences from typical oncaeid leg armature (= Type 1 in table 4 of Böttger-Schnack and Schnack 2013) marked in bold.

| Leg | ENDOPOD | EXOPOD |
|-----|---------|--------|
|     | enp-3   | exp-1  | exp-2 | exp-3 |
| P1  | 0,1,5   | I-0    | I-1   | I,1,4 |
| P2  | 0,1,3   | I-0    | I-1   | II,1,5 |
| P3  | 0,1,2   | I-0    | I-1   | II,1,5 |
| P4  | 0,1,1   | 0-0    | 0-1   | I,1,5 |