Acartiidae Sars G.O, 1903

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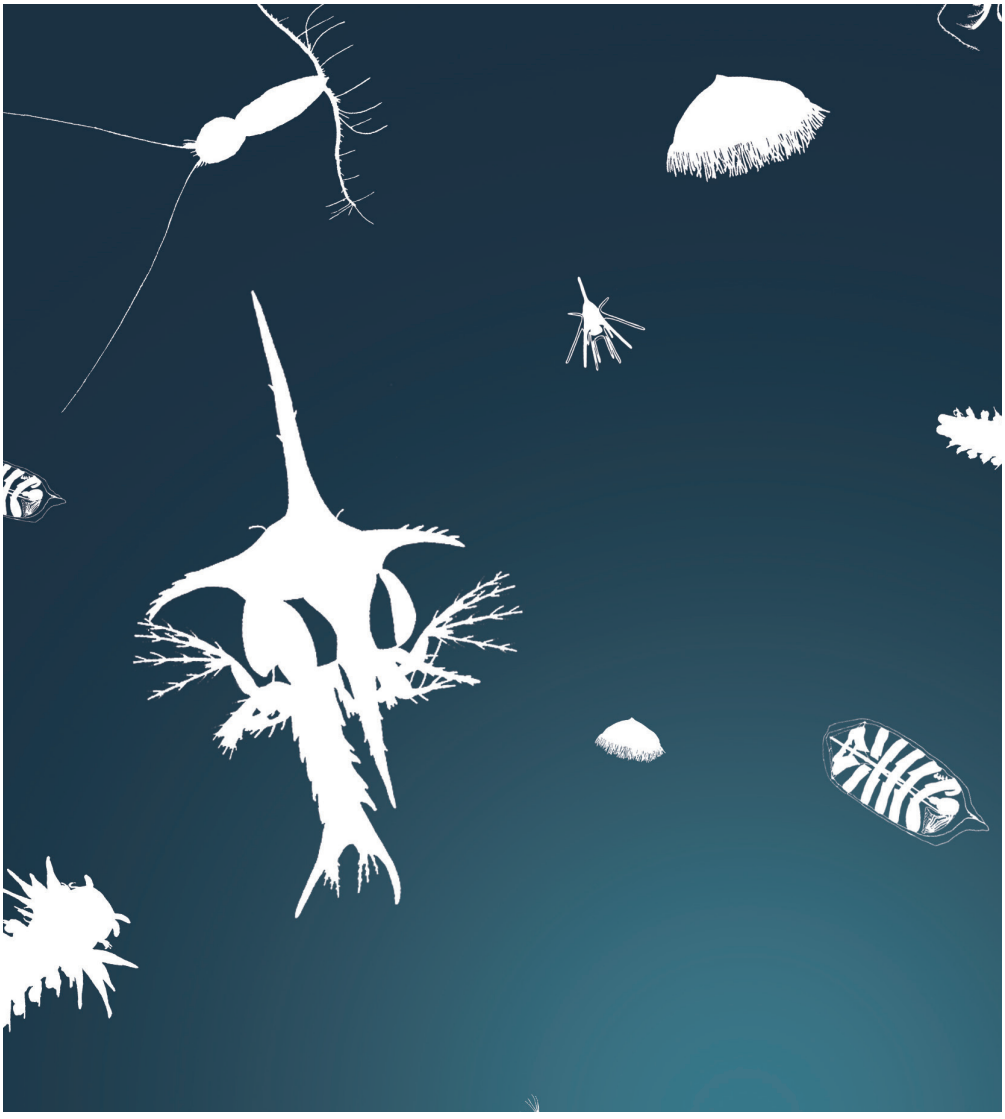

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Contents

Copepoda

Infraclass: **Neocopepoda**

Superorder: **Gymnoplea**

Order: **Calanoida**

Family: **Acartiidae Sars G.O., 1903**

Author: Genuario Belmonte

1 Summary

Copepods of the family Acartiidae are representatives of Calanoida. Common and abundant in marine zooplankton worldwide, the 86 recognized species of Acartiidae are grouped into 5 genera. They occur in neritic waters covering a wide latitudinal range. Adult body lengths range between 600 μm and 2700 μm, a size that is effectively captured by meso-zooplankton nets of 200 μm mesh size. Juveniles and nauplii, however, are smaller; they can only be quantitatively captured by using narrower mesh sizes. Adults show sexual dimorphism recognizable only after the first instars of the copepodite stage. This leaflet presents the following:

i) a key for the identification of the five genera included in the family Acartiidae; and

ii) the morphological features of 21 species and 1 variety considered as certain (among the 37 species+ 2 varieties reported) that belong to the genera *Acartia*, *Paracartia*, *Pteracartia* and occur in the eastern North Atlantic and Ponto-Mediterranean region.

A key to all these taxa is presented. This leaflet is an update of Plankton Identification Leaflet 181 (Bradford-Grieve, 1999a) in which 19 species plus 2 varieties were included and it is predominantly based upon Razouls *et al*. (2005–2020).

2 Introduction

Acartiidae are abundant and common components of marine plankton worldwide, and are particularly dominant in neritic-coastal and confined environments (either brackish or hypersaline). Acartiidae of coastal confined habitats are able to produce population swarms feeding typically on particulate organic matter and/or detritivorous microbes, which are abundant in such habitats. In general all the species are reported to have the ability to change their feeding behaviour if necessary; this ranges from small unicellular algae to Ciliophora, Rotifera, or even eggs of their own species (Saiz and Kiorboe, 1995; Drillet *et al*., 2014).

The family Acartiidae Sars, 1903 is represented today by 86 species (Razouls *et al*., 2005–2020), currently included in 5 genera:

- *Acartia* Dana, 1846;
- *Paracartia* Scott T., 1894;
- *Paralabidocera* Wolfenden, 1908;
- *Acartiella* Sewell, 1914; and
- *Pteriacartia* Belmonte, 1998.

Historical background

The first *Acartia* species (*A. negligens* and *A. tonsa*) were described by Dana (1849), three years after the genus description (Dana, 1846) that was assigned to the family Calanidae. The description was partial and inexact (e.g. "…antenna dextra maris antica non geniculante,…oculi duo inferiores et duo superiors."), and drawings of the new species were absent; this was probably the reason for scientists not assigning new specimens collected after 1849 to Acartiidae. Lilljeborg (1853) in fact created the new genus *Dias* for *D. longiremis*, a species evidently similar to the two described by Dana.

The genus *Dias* Lilljeborg 1853 was adopted for the description of some additional new species by Kriczaguin (1873) and Giesbrecht (1881); the latter, however, correctly re-established the genus *Acartia* Dana for the new species in a successive description (Giesbrecht, 1891). The acknowledgement of the 'precedence rule' in scientific nomenclature was stated by Giesbrecht with the dedication to Dana of one of his species described in 1889 (*A. danae*). *Dias latisetosus* Kriczaguin, 1873 was also transformed in *Acartia latisetosa*, but incredibly the other two *Dias* species (*D. ponteloides* and *D. longiremis* var. *spinifer*) of Kriczaguin were ignored. This was probably due to the language of the Kriczaguin report (Russian) that, similarly to the Latin used by Dana, prevented the complete assimilation of the new species into the western scientific community.

Dias latisetosus Kriczaguin, 1873 has been an emblematic case of misunderstanding; the species was found in Malta by Thompson (1888), who gave it the name *Acartia verrucosa* (also adopted by Giesbrecht [1893]), ignoring the Russian report from the north Black Sea area. Steuer (1929) recognized the coincidence of the two names and re-established the precedence of *latisetosa* over *verrucosa*. In the meantime *Acartia* had also been recognized as precedent to *Dias*, thus the species became *Acartia latisetosa*. Scott T. (1894) proposed the adoption of the new genus *Paracartia*, and so today the correct name of the species is *Paracartia latisetosa* (Kriczaguin, 1873). Nobody paid any attention, however, to the other two *Dias* species of Kriczaguin; examination of his original description allowed me to recognize *Dias longiremis* var. *spinifer* as the male of *P. latisetosa*.

This fact could have practical importance because the description of the variety that was ignored was one page before that of *D. latisetosus*. The position of the name allows us to recognize *longiremis spinosus* as the first name used for that species (or, more correctly, *spinosus*, because *longiremis* was already used for a different *Acartia* species). The name *latisetosa*, however, has been used for over 100 years, and this additional correction can be ignored to avoid confusion.

In 1903, Sars (1903) established a new family, Acartiidae, to group the 16 *Acartia* species officially described up until that time. Steuer (1923) then indicated 8 subgenera for all the *Acartia*, accepting the proposal of the sub-genus *Paracartia* suggested by T Scott (1894). Some of those subgenera (*Paracartia*, *Acartiella*), together with *Paralabidocera* and *Pteriacartia* which were added later (see Bradford-Grieve, 1999a; for a review), finally allowed copepodologists to recognize 5 genera belonging to the Family Acartiidae.

The first published drawings of a copepod of the Family Acartiidae, *Acartia longiremis*, are presented in Figure 1.

Species identification

Species identification in Acartiidae is traditionally based on the morphology of the adult, whereas nauplii are generally only identified at a taxonomic level not lower than family level (Bjornberg, 1972; Sazhina, 1985). The adult sexes present a marked dimorphism.

Acartiidae of the ICES area range in size from 600 μm to 2700 μm in females and from 670 μm to 2100 μm in males (Razouls *et al.*, 2005–2020). Only adults are efficiently captured by the commonly used meso-zooplankton nets (200 μm mesh size), while developmental stages (nauplii and copepodites) are missed or quantitatively under-sampled. The adult body size in marine Calanoida is generally affected by the season (with summer specimens smaller than winter ones) and habitat conditions and it is inversely correlated with the trophic state of the environment (Uye, 1994). Among Acartiidae, dwarf forms of *A. clausi* reported in confined environments by Grandori (1914) and Steuer (1929) might correspond to a different species (*A. margalefi* and/or *A. lefevrae* described by Alcaraz, 1976 and Bradford, 1976), as discussed in Belmonte and Potenza (2001). The size variability of adults is wider in females than in males, though females can regularly be smaller than males in geographically isolated populations (Belmonte and Cavallo, 1998).

In males, the right antennula (A1) is geniculated (although this is only evident macroscopically in species of the genus *Paracartia*) to grasp the female during mating; P5 is also modified to attach spermatophores to the genital openings of the female in the ventral side of her first urosomal segment. Females are generally fertilized just after the last exuviation (from CV to adult) and can be found with more than one spermatophore attached as a consequence of a mating competition. Females are free spawners, and lay their eggs directly in the water at a rate of 10–50 eggs f^{-1} day^{-1} (Ianora, 1998) for many days during their lifespan. Eggs are rounded, sometimes with a spiny chorion (Belmonte, 1998b). Contrary to the descriptions of Dana (1846) and Lilljeborg (1853), females never bear eggs in an egg sac. An 'apron' is present ventrally on the genital segment of females, which reaches to the furcal rami in some species (e.g. *Paracartia latisetosa*, *P. grani*, *Pteriacartia josephinae*); it is not clear if this represents an evolutionary regression of an ancient egg sac, or a sticking apparatus evolved to hold and protect the spermatophores attached to the female genital segment (Belmonte, 1992; 1998a). In Acartiidae, eggs can represent a diapause stage that allows the species to overcome adverse conditions. Acartiidae are the most represented in the list of Calanoida producing resting eggs (Belmonte and Rubino, 2019) which can be morphologically distinguishable from the subitaneous ones (Zillioux and Gonzales, 1972; Belmonte, 1992; 1997; 1998a; Belmonte and Puce, 1994; Belmonte and Rubino, 2019). Refer to Figure 2.

Size and morphological variability within the same species may hide the presence of cryptic species (Brylinski, 1984). In contrast, the same morphology may conceal high genetic variability of estuarine populations (Cervelli *et al*., 1995; Da Costa *et al*., 2011; Figueroa *et al*., 2020). The genetic dissimilarity (gene for 16S rRNA) of geographically distant populations of *A. tonsa* along the North American coasts is interpreted today as representing different genetic species, sharing a common morphology (Caudill and Bucklin, 2004; Figueroa *et al*., 2020).

The aim of this leaflet is to help morphologically identify the 21 species and 1 variety of Acartiidae present in the ICES area as well as in the adjacent Ponto-Mediterranean region. It represents an update of the last identification leaflet dedicated to this group (Bradford-Grieve, 1999a). The geographic distribution of species reported here is based on WoRMS, Razouls *et al*. (2005–2020), and the authors personal collection of papers on Acartiidae (about 2,000 articles spanning over 170 years).

3 Distribution

The family Acartiidae is widely distributed throughout the ICES area and Ponto-Mediterranean region, with a total of 21 species and 1 variety. The whole family may be defined as neritic and coastal, rather than oceanic. Only two species, *Acartia danae* and *A. negligens*, primarily inhabit open oceanic waters (Boxshall and Halsey, 2004). Some species are typical of confined waters and are considered inland fauna (Dussart and Defaye, 2002; Belmonte, 2018). In coastal confined environments, Acartiidae often occur in congeneric associations (Belmonte *et al*., 1989; Lakkis, 1994; Castro-Longoria and Williams, 1996; Aravena *et al*., 2009). The presumed large geographic distribution displayed by the single estuarine species *A. tonsa* is suspected to be the consequence of the grouping of different, cryptic, species under the same name (Caudill and Bucklin, 2004; da Costa *et al*., 2011; Figueroa *et al*., 2020).

A single species easily dominates meso-zooplankton in coastal and confined marine areas. This coastal adaptation is due to their feeding behaviour, which allows them to exploit the detrital food chain which is commonly well-sustained in coastal estuaries and confined areas. The population affirmation in estuaries and lagoons is also favoured by their resistance to ample variability of salinity and/or to hypoxic conditions, and enhanced by the capacity to produce resting eggs (Zillioux and Gonzales, 1972; Belmonte, 1992; 1997; 1998a; Belmonte and Puce 1994; Belmonte and Rubino, 2019). The latter allows them to remain inactive during temporary harsh conditions. At least two species, i.e. *Acartia tonsa* and *Paracartia grani*, have been reported to be expanding their geographic distribution and have appeared as non-indigenous species (NIS) in some areas (Belmonte and Potenza, 2001). They are reported as invasive in either brackish or hyperhaline coastal waters, where they have replaced local indigenous species (Belmonte *et al*., 2011; Annabi-Trabelsi *et al*., 2018; 2019).

The case of *A. tonsa*, is of remarkable interest. The species was one of the best known Acartiidae (the second to be described, in 1849) in the 19th century. It was, however, typical of South American coasts, and was reported in the ICES area only after 1927; this was from the French coast of the English Channel, and successively along the whole North Sea and Baltic Sea coasts up to the Gulf of Finland in 1936 (in Brylinsky, 1981). The species was reported in the Black Sea and northern Mediterranean region only after 1985 (Belmonte *et al*., 1994; Belmonte and Potenza, 2001), with a hypothesized diffusion from the Black to the Mediterranean seas. It is supposed that the arrival in the Black Sea occurred in ballast waters from the Baltic Sea via the Neva–Volga–Don–Azov Sea route (Gravili *et al*., 2010), and thanks to the resting eggs produced by the species. This southward expansion is still underway and *A. tonsa* has recently reached the North African coast (Annabi-Trabelsi *et al*., 2019), illustrated in Figure 3.

A southwards expansion of the geographic distribution involved two other Acartiidae (*A. clausi* and *Paracartia latisetosa*); these are considered among the few known examples of anti-Lessepsian migrants, i.e. those that have passed through the Suez Canal from the Mediterranean to the Red Sea (Fox, 1927; Dussart, 1989; Belmonte and Potenza, 2001), thus in the opposite direction of the standard Lessepsian migration (Por, 1978). In contrast, *Acartia centrura* and *A. fossae* entered the eastern Mediterranean Sea from the Red Sea through the Suez Canal (Zakaria, 2015). At extremes of the salinity tolerance of the family, *Paracartia latisetosa* has been found in the Nile river (salinity, 0 ‰) 200 km from the river mouth, and *Paracartia grani* in a saltern pond in Tunisia (salinity, 70 ‰) (Annabi-Trabelsi *et al*., 2018). The 21 species and 1 variety dealt with in the present report can be used to depict a gradient of species richness increasing from the Arctic area (1 species) to the subtropical Mediterranean (17 species). Subdivision of the ICES geographic area on the basis of the corresponding 15 FAO fishery zones allows us to distinguish common and rare species (Table 1). *Acartia longiremis*, *A. clausi*, and *A. tonsa* are the most widespread species (being absent only from 4, 5, and 6 zones, respectively),

while *A. centrura*, *A. enzoi*, *A. fossae*, and *A. omorii* are reported only in 1 zone of the considered area. All these species, with the exception of *A. fossae*, are very common elsewhere; meanwhile *A. enzoi* has been reported exclusively from the western Mediterranean Sea (i.e. it is endemic to the ICES geographic area). Other endemic species of the ICES area, besides displaying a wide distribution inside it, are: *A. adriatica*, *A. discaudata*, *A. italica*, *A. teclae*, and *Pteriacartia josephinae*.

4 Morphological characteristics

Recent studies (Srinui *et al*., 2019; Lee *et al*., 2019) propose genetic molecular tools for new *Acartia* species description. As these are not, however, available for all species of even a single family, the morphological approach remains the one commonly applied for species identification in most research laboratories. On the basis of morphological characters, the genera of the ICES area can be distinguished as follows (Bradford-Grieve, 1999b, p. 213; Boxshall and Halsey, 2004, p. 50).

Female features

Figures 4 and 5.

i) One single eye visible dorsally.

ii) Cephalosome and first pedigerous somite separated, pedigerous somites 4 and 5 always fused.

iii) Posterolateral corners of prosome rounded, and characterized by the presence of points, spines, hairs.

iv) Urosome 3-segmented. The first segment derived from the fusion of two somites.

v) Genital apparatus with paired gonopores and copulatory pores situated in paired slits (not concealed beneath a common operculum), typically located either adjacent to midline on ventral surface of the genital double-somite, or located ventro-laterally on the double-somite, as in *Paralabidocera*; paired seminal receptacles usually present, rarely absent, as in *Acartiella*.

vi) Anal operculum may be on the anal segment, or anus may open between the last two urosome segments into a dorsal groove of the final segment.

vii) Furcal rami generally slightly asymmetrical, sometimes fused with the anal segment, each one with up to 6 setae.

viii) Rostrum (with or without paired filaments).

ix) A1 with 17–22 articles, many articles with long setae. Several compound articles in the proximal part; distal articles (antennomeres XXIV, XXV, XXVI) all typically free, not fused to the apical article which is in turn the fusion result of the last two antennomeres XXVII–XXVIII.

x) A2 biramous. Coxa with 1 seta. Basis and first endopodal article forming elongate allobasis bearing 6 to 8 proximal and 1 distal setae along the inner margin. The 6–8 proximal setae are interconnected by basal tendinous strands extending from a single muscle inserted adjacent to the last seta, allowing the 8 setae to be moved as a single unit. Endopod article 2, elongate with 6–9 distal setae. Endopod article 3, small, bearing 5 setae plus 2 fused setae (representing the vestigial fourth article). Exopod short, 4-articled with

1, 2, 2, 3 or 2, 1, 1, 3 setae respectively. Endopod apparently reduced to short article bearing 9 setae in *Acartiella*.

xi) Labrum large, prominent, tri lobate

xii) Md with coxa showing a well-developed gnathobase with a large separate tooth on one border; palp basis with 1–2 setae; indistinctly 2-articulated endopod with 2 + 8–9 setae; exopod 5-articulated with 1, 1, 1, 1, 2 setae. Palp often with setation reduced, or palp sometimes vestigial or absent.

xiii) Mx1 with reduced lobes and setation. Inner lobe 1 (prae-coxal article) short with 6–8 spines and setae; inner lobes 2 and 3 plus basis, with 0, 3, 1 setae. Basis, endopod and exopod fused; exopod with 2 + 5 setae; outer lobes 1 and 2 with 8–9 and 1–0 setae.

xiv) Mx2 with pre-coxa and coxa separate, setation formula of 4 endopod articles variable: 3-4, 2-3, 2-3, 1-3 ; basis with 2 setae ; exopod 4-articulated, setation formula 1, 1, 1, 2.

xv) Mxp 4-articulated; robust syncoxa and reduced distal part of limb; syncoxa with up to 5 well developed spinulate setae; basis and 2-articulated endopod bearing 1, 3, 2 short setae; proximal endopod article with indication of subdivision into 3 sub-articles; often with setation reduced.

xvi) Swimming legs P1-P4 biramous, slender and delicate with 3-articulated exopods and 2-articulated endopods, equipped with long plumose setae;

xvii) Distolateral border of exopod articles of P2-P4 expanded into conspicuous spiny processes.

xviii) Inner seta on basis of P1 absent.

xix) Terminal spine of exopod of P2–P4 with outer edge toothed.

xx) Female P5 usually uniramous, small, symmetrical, 3-articulated; coxa and coupler (intercoxal sclerite) may be fused or coxa and basis and the coupler may be fused (*Paracartia*); basis with an outer seta; exopod in the form of a spine or elongate seta; small endopod present only in *Acartiella*.

Male features (differing from the female)

Figures 6 and 7.

i) Urosome 5-segmented. Single genital aperture located ventro-laterally at posterior rim of genital somite on right side.

ii) A1 usually prehensile on the right side only, with 12–18 articles; middle articles may be greatly swollen. Secondary fusions of antennomeres, distal to geniculation, typically interesting antennomeres XXI–XXIII, XXIV–XXVI and XXVII–XXVIII, or XXIV–XXVIII.

iii) P5 each uniramous, asymmetrical, attached to a plate formed by the fusion of coxae and the coupler. Basis usually asymmetrically developed with an outer distal seta; left leg with 2-articulated exopod (3-articulated only in *Paracartia africana*), article 2 with variously decorated tip; right leg usually a 3-articulated exopod, articles 1 and 2 often displaying inner processes; article 3 opposed to the process present on article 2 to form a subchela.

5 Taxonomic Key

Acartiidae genera

Modified from Boxshall and Halsey (2004, p. 52)

1. Female P5 biramous; left A1 in both sexes 21 or 22 articulated……..... **2**
Female P5 uniramous; left A1 in both sexes 18 or 19 articulated……..... **3**

2. A2 endopod reduced, about as long as exopod; female A1 21-articulated.....
..... ***Acartiella***
A2 endopod A2 elongate, much longer than exopod; female A1 22-articulated.....
..... ***Paralabidocera***

3. Posterolateral angles of prosome expanded into processes; plumose seta of male P5 shorter than terminal claw..... ***Paracartia***
Posterolateral angles of prosome rounded, not expanded; female P5 reduced to minute lobe bearing a single apical seta..... ***Pteriacartia***

Posterolateral angles of prosome rounded or pointed, not wing-like; plumose set of male P5 typically longer than terminal claw..... ***Acartia***

Species of family Acartiidae from the ICES area

Modified from Bradford-Grieve (1999a).

Genus *Acartia* Dana, 1846

Female (Figures 4 and 5)

1. Rostral filament absent..... **2**
Rostral filament present..... **9**

2. Anal segment much wider than URS 2 in dorsal view (Figure 4di)..... ***A. discaudata***
Genital double somite ventrally prominent, with a chitinous button on the right side (Figure 4dim)..... ***A. discaudata* var. *mediterranea***

Anal segment not wider than URS 2 in dorsal view..... **3**

3. Genital double-somite with a ventral prominence, posterior to genital openings; in dorsal view genital double-somite twice the length of URS 2 in dorsal view, and with an

anterior angular swelling (Figure 4e)..... ***A. enzoi***

Genital double-somite with a smoothly curving ventral surface..... **4**

4. Anal somite spinous; posterior PRS with 1 very large and several small spines, genital double-somite and URS 2 with surface spinules as well as posterior spines (Figure 4l)..... ..... ***A. longiremis***

Anal somite naked or with very fine spinules..... **5**

5. Genital ventral swelling placed anteriorly..... **6**

Genital ventral swelling approximately central..... **7**

6. PRS with posterior hairs; length of right furcal ramus less than twice width (1.69–1.91) (Figure 4h)..... ***A. hudsonica***

PRS with postero-dorsal spines; length of right furcal ramus more than twice width (2.12–2.43) (Figure 4ma)..... ***A. margalefi***

PRS with postero-lateral horns and postero-dorsal spines, posterior rim of genital double somite and URS 2 with spines (Figure 4ce)..... ***A. centrura***

7. Posterior PRS naked or with ventral hairs..... **8**

Posterior PRS bearing spines; P5 terminal spine thick, length of right furcal ramus Usually less than twice width (Figure 4cl)..... ***A. clausi***

8. Large species (total length 0.94-1.05 mm) with URS 2 naked or with 1-3 posterodorsal blunt teeth. Right furcal ramus length: width ratio = 1.50:1.82 (Figure 5o).... ***A. omori***

Small species (total length 0.71–0.87 mm) with naked URS. Right furcal ramus length:

width ratio = 1.71:2.20 (Figure 5te)..... ***A. teclae***

9. External plumose seta of P5 clearly shorter than terminal spine, B2 twice as long as wide (Figure 5i)..... ***A. italica***

External plumose seta of P5 about equal in length to terminal spine..... **10**

External plumose seta of P5 longer or much longer than terminal spine..... **11**

10. URS integument covered with very fine spinules (abundant or rare). Spine on P5 finely, haired at its tip and variably oriented (straight to bent) (Figures 4b, 5b)..... ***A. bifilosa***

URS 1 and 2 with postero-dorsal spinules. Spine on P5 denticulate at its tip and straight, B2 with an internal projection (Figure 5to)..... ***A. tomsa***

PRS postero-dorsal rim richly spinulose (spines of different size); posterior rim of genital double somite and URS 2 with spinules (Figure 5pl)..... ***A. plumosa***

11. Spine on P5 bent outward, long, internal border toothed (Figure 5a)..... ***A. adriatica***

Spine on P5 bent to outside, short, thick, its internal border toothed (Figure 5mp)..... ..... ***A. macropus***

Spine on P5 not bent, finely or moderately toothed on both borders..... **12**

12. External plumose seta on P5 less than 1.5 times as long as spine (Figure 5f).... ***A. fossae***

External plumose seta on P5 3 times as long as spine (Figure 5d)..... ***A. danae***

External plumose seta on P5 5 times as long as spine (Figure 5n)..... ***A. negligens***

Male (Figures 6 and 7)

1. Rostral filaments absent..... **2**

Rostral filaments present..... **8**

2. Right P5 Re1 expanded at inner distal border, left B2 with one isolated strong spine (Figure 7di)……..... ***A. discaudata***

Right P5 Re1 not expanded at inner distal border, left B2 with two rows of spines, of different strength. Re3 length:width ratio less than 2.0 (Figure 7dim)..... ..... ***A. discaudata* var. *mediterranea***

Right P5 Re1 not expanded at inner distal border, left B2 with one long row of strong spines (Figure 7e)..... ***A. enzoi***

Right P5 Re1 not expanded at inner distal border, left B2 without spines or setae (Figure 7ce)..... ***A. centrura***

Right P5 Re1 expanded at inner distal border, left B2 otherwise ornamented..... **3**

3. Left P5 B2 with 2 types of spines or spinules on posterior surface, one type very large (Figure 7l)..... ***A. longiremis***

Left P5 B2 with spinules of uniformly small size on posterior surface…..... **4**

4. Left P5 Re2f3 longer than or equal to Re1..... **5**

Left P5 Re2f3 shorter than Re1..... **6**

5. Posterior PRS border with posterodorsal spinules and posterior hairs. P5 right Re2 inner lobe rounded terminally (Figure 6ma, 7ma)..... ***A. margalefi***

Posterior PRS border with posteroventral hairs. P5 right Re2 inner lobe angular because of 2 terminal processes giving it a slightly bilobed appearance (Figure 7te).... ***A. teclae***

6. Posterior PRS with posterodorsal spines and posterior stiff hairs (Figure 6 cl, 7 cl).... ..... ***A. clausi***

Posterior PRS with posteroventral hairs..... **7**

7. Left P5 Re2f3 with long equal spines, each more than half length of segment, anterior stout spine inserted proximal to posterior spine; right Re2 with outer edge spines (Figure 7o)..... ***A. omori***

Left P5 Re2+3 with long equal spines about half length of article, each inserted at same level distally on article; right Re2 outer edge naked (Figure 7h).....***A. hudsonica***

8. Posterior PRS corners rounded, often bearing small spines or hairs..... **9**

B2 of left and right P5 with an internal pointed extension, right Re1 with a long, thin, inner, distal appendix (Figure 6da, 7da)..... ***A. danae***

9. Left P5 Re2+3 in form of a pincer with a heavy outer spine. Inner appendix on right. Re2 narrow and elongate..... **10**

Left P5 Re2f3 not in form of a pincer. Right Re2 with a wide, short appendix or without any appendix..... **11**

10. Right P5 Re2 inner appendix placed on very distal part of article. Re3 not much longer than Re2 appendix. Right B2 with proximal inner expansion (Figure 7a).. ***A. adriatica***

Right P5 Re2 inner appendix placed on very distal part of article. Re3 much longer than Re2 appendix. Right B2 with small proximal inner expansion (Figure 7pl).. ***A. plumosa***

Right P5 Re2 inner appendix arises from middle to proximal part of article. Re3 more than twice as long as Re2 appendix. Right B2 without prominent inner expansion (Figure 7mp)..... ***A. macropus***

11. Right P5 Re2 without conspicuous inner expansion. Left Re1 with a long outer distal inner border spine, Re2+3 with 3 terminal spines and 1 longer spine inserted at about mid length on inner border (Figure 7n)..... ***A. negligens***

Right P5 Re2 with a conspicuous inner expansion. Left Re1 outer distal border naked, Re2+3 with 1 terminal spine and at least 1 other spine..... **12**

12. Right P5 Re1 with a moderately sized, broadly rounded distal expansion (Figure 7b)... ..... ***A. bifilosa***

Right P5 Re1 without a distal expansion, or small expansion and a long posterior surface spine..... **13**

13. Right P5 Re1 with a long posterior surface spine which arises midway along its article and extends half way along Re2; Re2 with width of base of inner expansion less than half length of article. Left B2 with a small inner triangular knob (Figure 7f)... ***A. fossae***

Right P5 Re1 without a long spine on posterior surface. Re2 with width of base of inner expansion less than half length of article. Left B2 without inner tooth. Right B2 with small proximal triangular tooth (Figure 7i)..... ***A. italica***

Right P5 Re1 without a long spine on posterior surface. Re2 with width of base of inner expansion approximately equal to length of article. Left B2 with a broadly rounded inner expansion. Right 52 with a large proximal broadly rounded expansion (Figure 7to)..... ..... ***A. tonsa***

Genus *Paracartia* Scott T., 1894

Female (Figure 5)

1. Genital double-somite symmetrical with widest part posterior, in dorsal view. P5 with a heavy terminal spine and very small external plumose seta (Figure 5Pag)..... ***P. grani***

Genital double-somite symmetrical with widest part anterior, in dorsal view. P5 with a long terminal spine and very small external plumose setae (Figure 5Pal)..... ..... ***P. latisetosa***

Male (**Figures 6 and 7)**

1. Right A1 with middle articles swollen, outer middle spine on articles 19–21 very large, extending almost to end of A1. Right P5 B1 with long triangular appendix, Re2 with proximal rounded appendix less than 1/3 length Re3 (Figure 6Pag, 7Pag)..... ***P. grani***

2. Right A1 with middle articles not swollen, outer middle spine on articles 19–21 long, moderately large extending to point of fusion of articles 22 and 23. Right P5 B1 with a triangular appendix, Re2 with proximal rounded appendix less than 1/3 length Re3 (Figure 7Pal)..... ***P. latisetosa***

Genus *Pteriacartia* Belmonte, 1998

P. josephinae (Crisafi, 1974) is the only species of the genus.

Female (Figure 5)

Posterior prosome rounded. Genital double-somite carrying a tapering, posterolateral appendix on right which extends almost to posterior border of anal somite; genital apertures laterally placed. The double genital somite shows always an attached spermatophore accompanied by an asymmetrical oval apron (a lamella, in Bradfrord-Grieve, 1999a) which is spread out beneath urosome and extends to right and to just beyond caudal rami.
No setae on caudal rami enlarged. Pedigerous somites 1 and 2 appear to be fused. P5 is minute and slender (if compared with all other thoracic legs), each leg bearing only a plumose seta.

Male (Figures 6 and 7)

Right geniculate A1 without a specially widened section. Right P5 B2 with two, small inner swellings, distalmost of which is triangular in shape, Re2 with a long, thin, distal appendix, Re3 with a centrally placed outer keel; left Re2+3 with an inner rounded appendix terminated by a

pointed spine, outer corner terminated in a similar spine, between these two corners is a raised, hairy area (Crisafi, 1974). Right geniculate A1 without a specially widened section. Right P5 B2 with two, small inner swellings, distalmost of which is triangular in shape, Re2 with a long, thin, distal appendix, Re3 with a centrally placed outer keel; left Re2+3 with an inner rounded appendix terminated by a pointed spine, outer corner terminated in a similar spine, between these two corners is a raised, hairy area (Crisafi, 1974).

The range of body size in each sex is reported in Table 2.

Taxonomic problems

Species are not correctly reported, or dubious reports are either not confirmed or still under discussion in the case of the following 19 taxa.

Acartia bifilosa* var. *inermis

The variety was created on the basis of the complete lack of setulae on the dorsal cuticle of female urosome segments (Figures 4 and 5). Urosome of *A. inermis* specimens, however, have been re-examined by Hirst and Castro-Longoria (1998) who discovered that preserved specimens had not really naked urosome. In addition to this, a morphological *continuum* between hairy and 'naked' specimens seemed to exist. The two varieties of *A. bifilosa* (*inermis* and *intermedia*) were proposed as invalid for this reason.

Acartia discaudata* var. *mediterranea

Bradford (1976) proposed the elevation of this variety to the rank of species, due to differences in the genital double somite of females and of the first article of the left P5 in males (Figure 6 and 7). Although the new species has never been accepted as such, the existing differences between Mediterranean and northern Europe populations largely justify the separation of the two taxa; Bradford-Grieve presented them separately in her Plankton Identification Leaflet on Acartiidae (1999a). The present leaflet confirms such a proposal and lists the two taxa separately.

Dias ponteloides

The species was reported by Kriczaguin (1873) as a small copepod (body length, 0.6 mm). The species was never accepted, but it probably corresponds to *Acartia margalefi* Alcaraz 1976, successively reported from the Black Sea (Belmonte and Mazzocchi, 1997).

Acartia elmaghraby

This species has been reported only by Kovalev and Shmeleva (1982), and a standard description does not exist. The holotype and/or the original sample from which it was taken have not been deposited (Belmonte and Potenza, 2001). This species is a *nomen nudum* (see also Bradford-Grieve, 1999a).

Acartia enzoi

Described and reported only once, by Crisafi (1974). Considered as a synonym of *A. discaudata* var. *mediterranaea* (Razouls *et al*., 2005–2020). The similarity with that last species, however, is only seen in the female; the male P5 is easily distinguishable. Holotype and paratypes are not available. The name remains valid for the characteristic male morphology. This species has been recently reported in coastal waters of the southern Tyrrhenian Sea (Margiotta *et al*., 2020).

Paracartia dubia

A species of the tropical Atlantic and Indian oceans. Reported by Mazza (1966) as present in the Mediterranean basin, but without a precise geographic reference. The species has not been reported from the ICES area in the succeeding 54 years.

In the period between 2000 and 2010, the list of Black Sea copepods was enriched by 14 *Acartia* species new to science (Unal *et al*., 2002; Shmeleva *et al*., 2008 and 2009; Pavlova and Shmeleva, 2010). Six of these were not reported with the correct original spelling, according to Article 32 of the International Code of Zoological Nomenclature, and three (*A. lamasii*, *A. vivesei,* and *A. zaitsevi*) have a complete lack of description (*nomina nuda)* and are not acceptable. The remaining five species (*A. hasanii*, *A. ioannae*, *A. janetae*, *A. eremeevi*, and *A. mollicula*), although present in official literature, were described with contradictions between text and figures, or even with drawings that lacked the necessary details (Gubanova *et al*., 2014). The P5 of all these five species were found to be very similar to those of juveniles (copepodites) of previously described species. This situation does not, consequently, allow us to consider these new species from the Black Sea (and ICES area) as valid.

5 Tables

Table 1. Distribution of Acartiidae species in the geographical subdivision of ICES area (= FAO fishery main zones)

Species	ICES/FAO zones (code)															Extra ICES presence
	I	II	III	IV	V	VI	VII	VIII	IX	BAL	34.1	37.1	37.2	37.3	37.4	
Acartia adriatica												x	x	x		
Acartia bifilosa			x	x			x	x		x		x	x			x
Acartia centrura														x		x
Acartia clausi			x	x			x	x	x	x		x	x	x	x	x
Acartia danae								x	x		x	x	x	x		x
Acartia discaudata			x	x			x			x						x
Acartia discaudata mediterranea								x	x			x	x	x		
Acartia enzoi												x				
Acartia fossae														x		x
Acartia hudsonica				x	x	x	x									x
Acartia italica							x					x	x	x	x	
Acartia longiremis	x	x	x	x	x	x	x			x		x	x	x		x
Acartia margalefi		x					x	x				x	x		x	
Acartia macropus									x							x
Acartia negligens							x	x	x			x	x	x		x
Acartia omorii							x									x
Acartia teclae		x										x				
Acartia tonsa			x	x			x	x		x		x	x	x	x	x
Paracartia grani		x		x			x	x	x			x	x	x		x
Paracartia latisetosa								x				x	x	x	x	x
Pteriacartia josephinae												x	x	x		

Table 2. Size range (mm) of adult female and male of each Acartiidae species in the ICES area (*A. discaudata* and *A. discaudata* var. *mediterranea* are considered together). Data from Razouls *et al.* (2005–2020) and Belmonte and Cavallo (1997).

Species	Female	Male
Acartia adriatica	1.05–1.039	1.180–1.280
Acartia bifilosa	0.672–1.250	0.667–1.250
Acartia centrura	1.130–1.30	1.025–1.030
Acartia clausi	0.600–1.47	0.680–1.340
Acartia danae	0.900–1.340	0.700–1.100
Acartia discaudata	1.000–1.200	0.900–1.100
Acartia enzoi	1.067–1.072	1.052
Acartia fossae	0.900–1.400	0.910–1.300
Acartia hudsonica	0.740–1.320	0.710–1.070
Acartia italica	0.700–1.000	0.700–1.000
Acartia longiremis	0.802–1.400	0.659–1.220
Acartia macropus	1.18	1.23
Acartia margalefi	0.622–0.867	0.665–0.872
Acartia negligens	0.910–2.070	0.800–1.500
Acartia omorii	0.900–1.300	0.800–1.200
Acartia plumosa	0.900–1.300	1.000–1.130
Acartia teclae	0.710–0.870	0.640–0.790
Acartia tonsa	0.821–1.500	0.770–1.340
Paracartia grani	0.900–1.260	0.950–1.120
Paracartia latisetosa	0.766–1.230	0.750–1.200
Pteriacartia josephinae	0.796–0.865	0.788–0.865

6 Figures

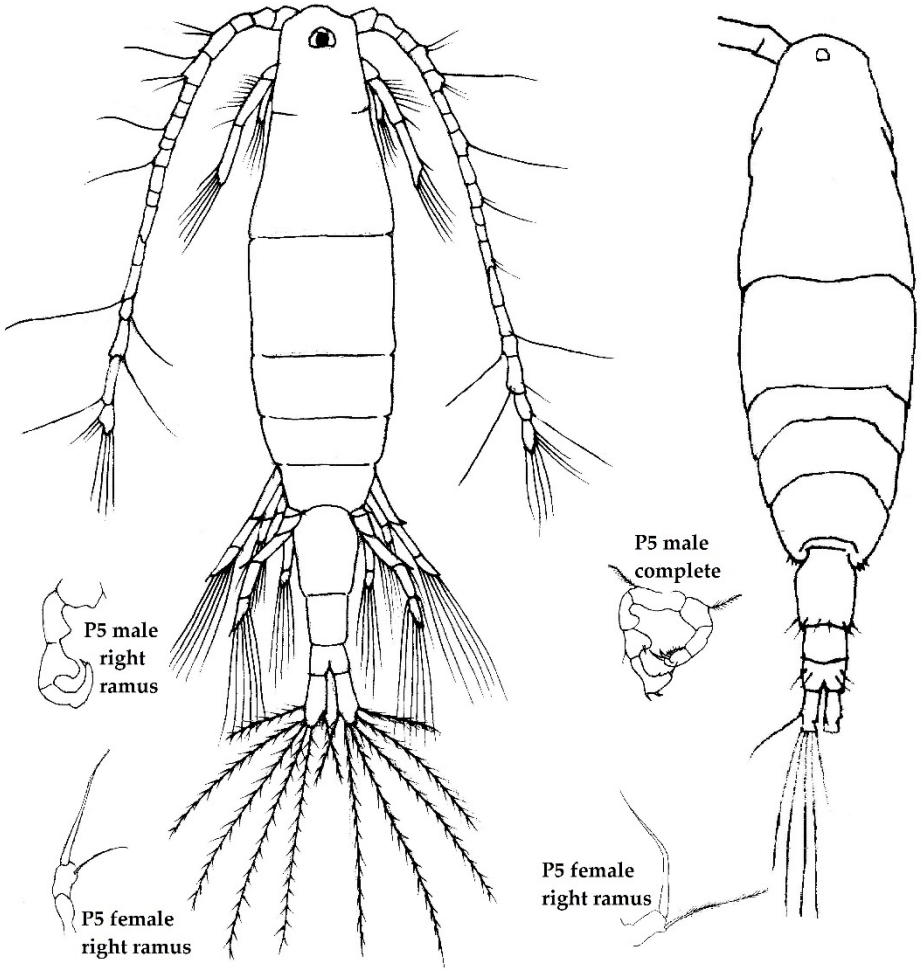

Figure 1. First drawings of a copepod of the family Acartiidae: *Acartia longiremis*. Adult female, left, Lilljeborg (1853); right, Giesbrecht (1893). In both cases also P5 of male (entire, for the Giesbrecht drawing, only the right ramus for the Lilljeborg drawing) and of female (only the right ramus) are represented. The species is now identified on the basis of spinules on URS segments, a detail that was disregarded by Lilljeborg (1853).

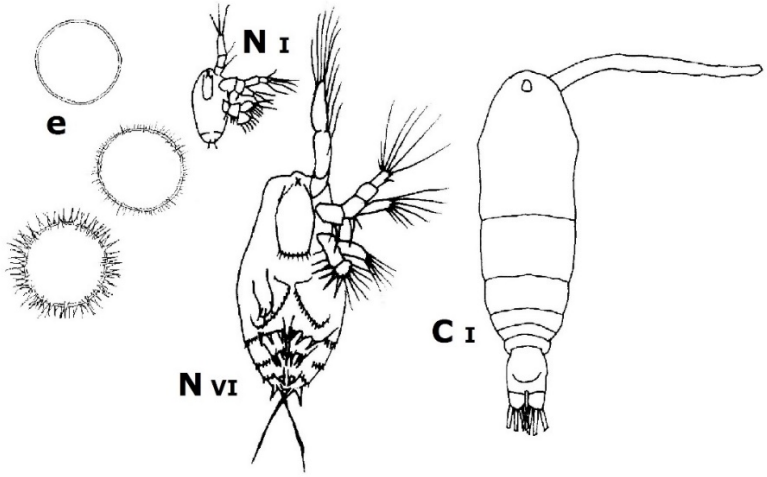

Figure 2. Developmental stages of Acartiidae. e, eggs (with a smooth or spiny chorion); N I and N VI, first and last nauplius instars; C I, first copepodite (juvenile) instar. Re-drawn from different sources.

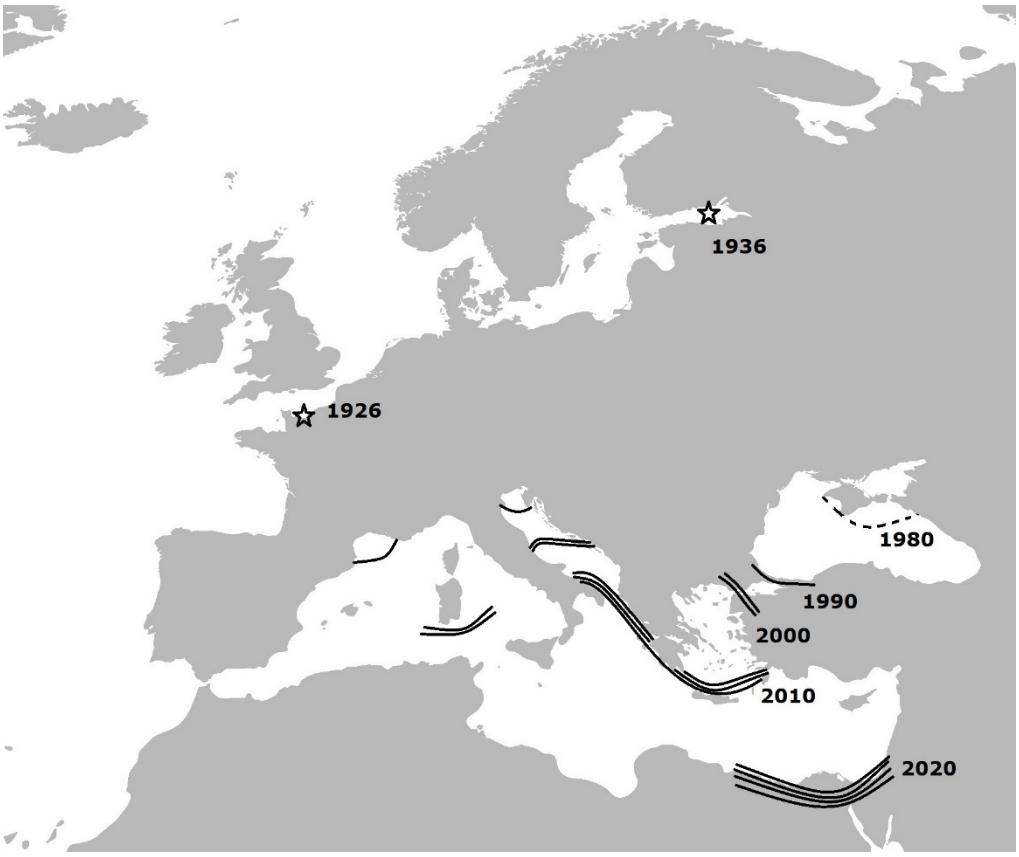

Figure 3. Chronological expansion of *Acartia tonsa* geographic distribution in ICES area. Different types of lines delimit age of reports (dotted, until 1980; simple, 1990; double, 2000; triple, 2010; quadruple, 2020)

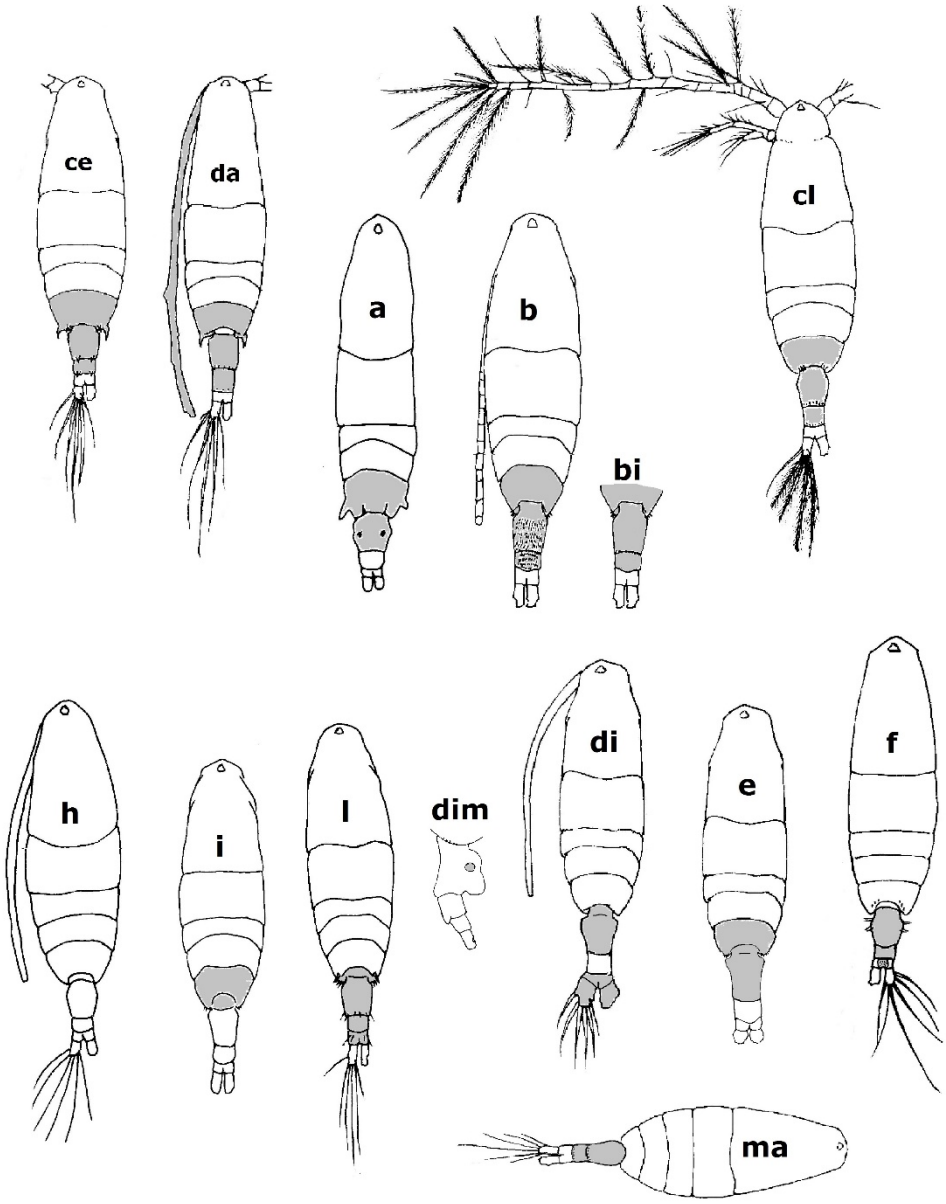

Figure 4. Dorsal view of adult females of 12 Acartiidae species reported for ICES area. Coloured parts of silhouettes are those useful for the species identification.

a, *Acartia adriatica*; **b**, *A. bifilosa*; **bi**, *A. bifilosa* **var.** *inermis*; **ce**, *A. centrura*; **cl**, *A. clausi*; **da**, *A. danae*; **di**, *A. discaudata*; **dim**, *A. discaudata* **var.** *mediterranea*; **e**, *A. enzoi*; **f**, *A. fossae*; **h**, *A. hudsonica*; **i**, *A. italica*; **l**, *A. longiremis*; **ma**, *A. margalefi*.

..

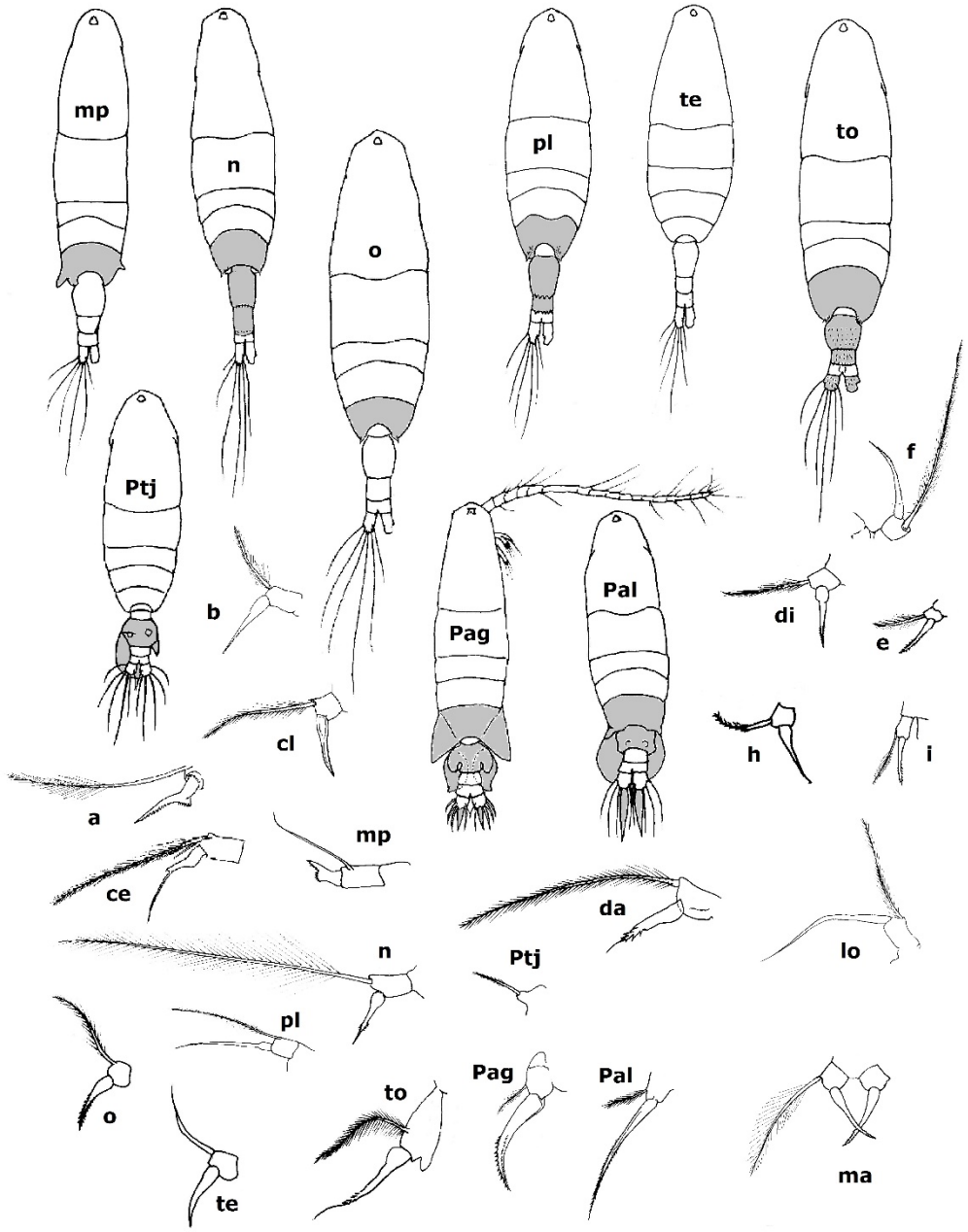

Figure 5. Dorsal view of adult females of 9 Acartiidae species *reported for ICES area,* **and P5 of 21 females (only the right ramus). Coloured parts of silhouettes are those useful for the species identification.**

a, *Acartia adriatica*; **b**, *bifilosa*; **bi**, *A. bifilosa* **var.** *inermis*; **ce**, *A. centrura*; **cl**, *A. clausi*; **da**, *A. danae*; **di**, *A. discaudata*; **dim**, *A. discaudata* **var.** *mediterranea*; **e**, *A. enzoi*; **f**, *A. fossae*; **h**, *A. hudsonica*; **i**, *A. italica*; **l**, *A. longiremis*; **ma**, *A. margalefi*; **mp**, *A. macropus*; **n**, *A. negligens*; **o**, *A. omori*; **pl**, *A. plumosa*; **te**, *A. teclae*; **to**, *A. tonsa*; **Pag**, *Paracartia grani*; **Pal**, *Paracartia latisetosa*; **Ptj**, *Pteriacartia josephinae*.

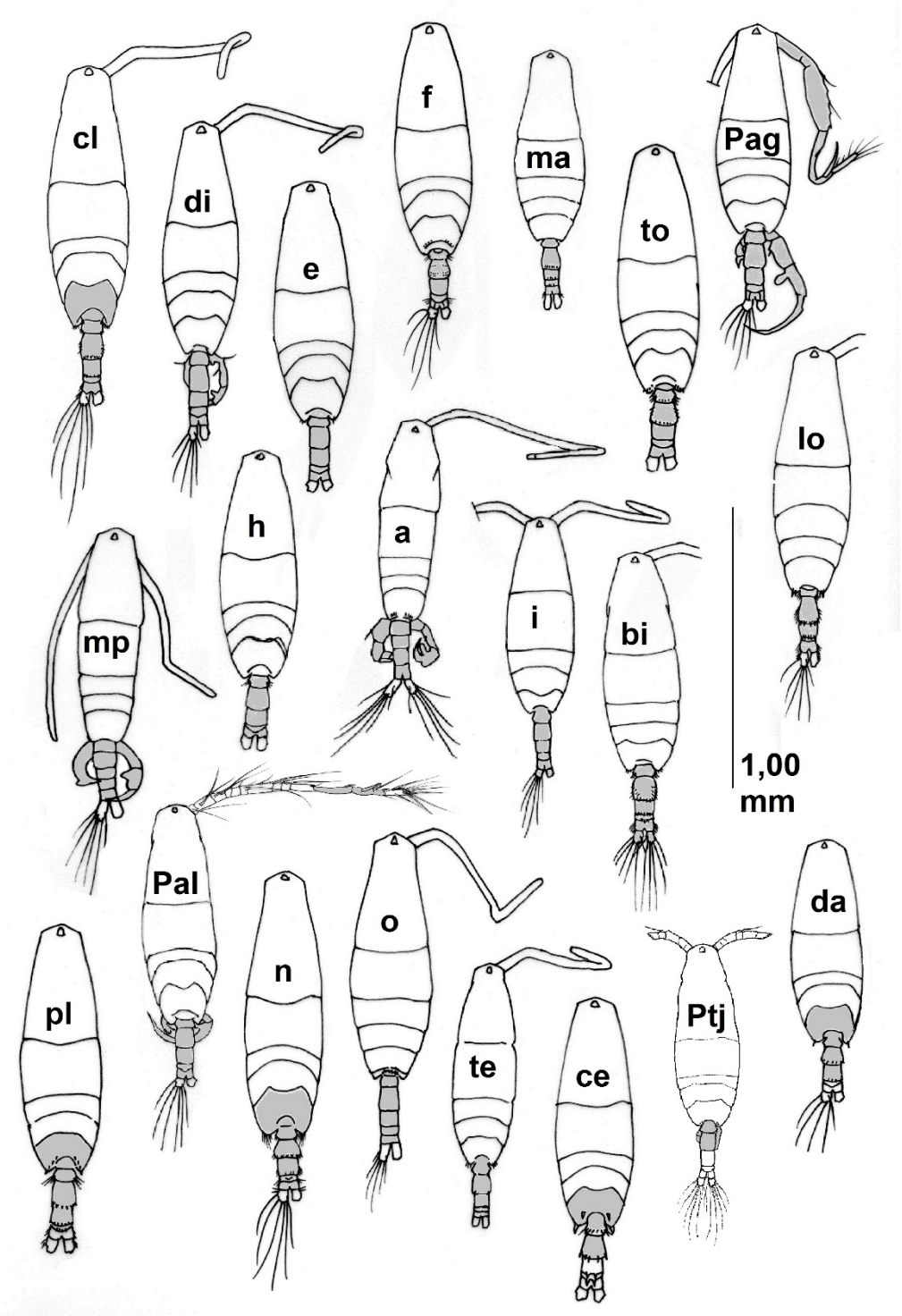

Figure 6. Dorsal view of adult males of 21 Acartiidae species (the 2 varieties, *bifilosa inermis*, and *discaudata mediterranea*, are not showed) reported for ICES area. Coloured parts of silhouettes are those useful for the species identification.

a, *adriatica*; **b**, *bifilosa*; **ce**, *centrura*; **cl**, *clausi*; **da**, *danae*; **di**, *discaudata*; **e**, *enzoi*; **f**, *fossae*; **h**, *hudsonica*; **i**, *italica*; **l**, *longiremis*; **ma**, *margalefi*; **mp**, *macropus*; **n**, *negligens*; **o**, *omori*; **pl**, *plumosa*; **te**, *teclae*; **to**, *tonsa*; **Pag**, *Paracartia grani*; **Pal**, *Paracartia latisetosa*; **Ptj**, *Pteriacartia josephinae*.

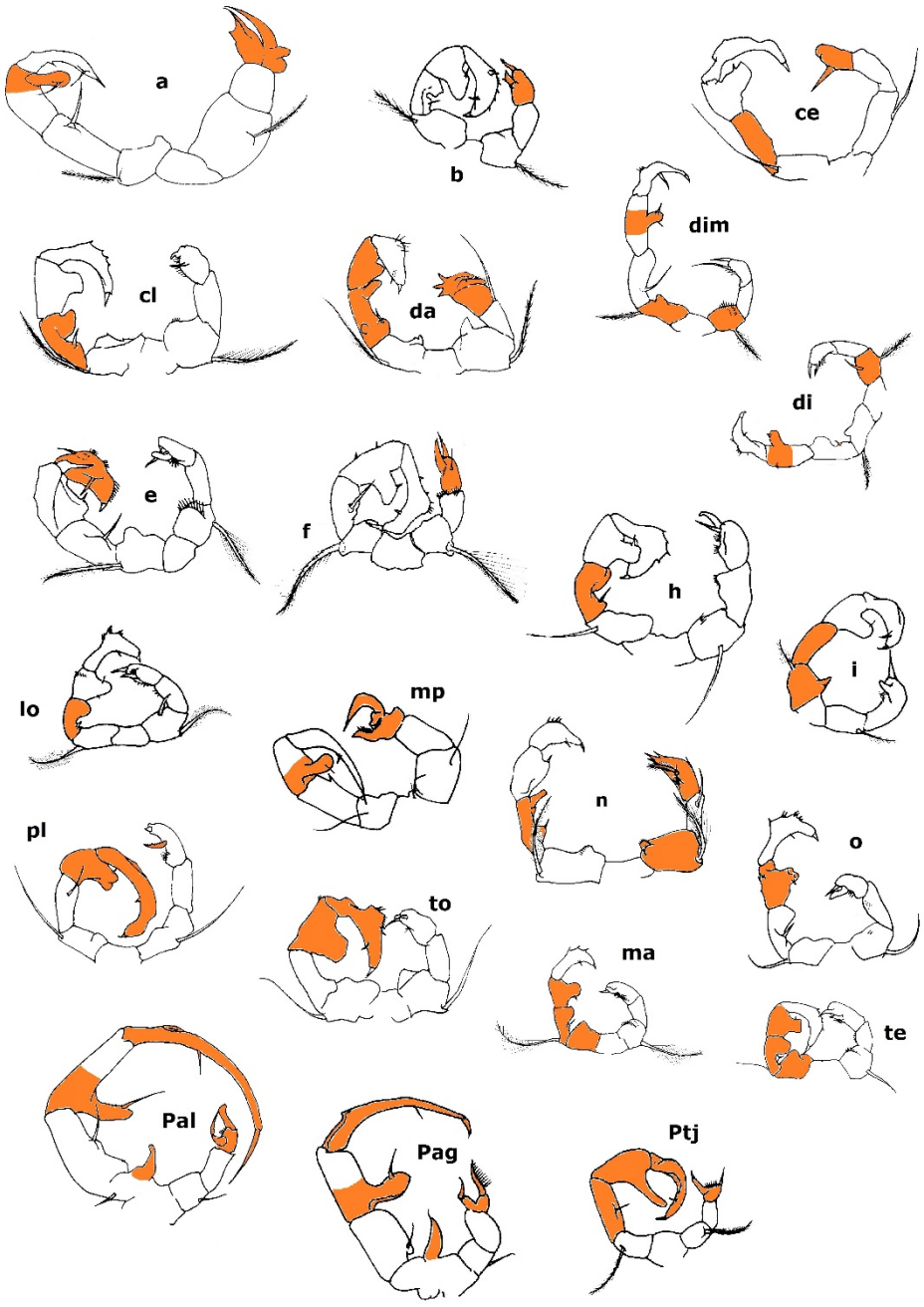

Figure 7. Representations of 21 male P5 plus the variety *discaudata mediterranea*. Coloured parts of are those useful for the species identification.

a, *Acartia adriatica*; **b**, *A. bifilosa*; **ce**, *A. centrura*; **cl**, *A. clausi*; **da**, *A. danae*; **di**, *A. discaudata*; **dim**, *A. discaudata* **var.** *mediterranea*; **e**, *A. enzoi*; **f**, *A. fossae*; **h**, *A. hudsonica*; **i**, *A. italica*; **l**, *A. longiremis*; **ma**, *A. margalefi*; **mp**, *A. macropus*; **n**, *A. negligens*; **o**, *A. omori*; **pl**, *A. plumosa*; **te**, *A. teclae*; **to**, *A. tonsa*; **Pag**, *Paracartia grani*; **Pal**, *Paracartia latisetosa*; **Ptj**, *Pteriacartia josephinae*.

7 Links to further information

WoRMS

A. adriatica; http://www.marinespecies.org/aphia.php?p=taxdetails&id=346047

A. bifilosa; http://www.marinespecies.org/aphia.php?p=taxdetails&id=345919

A. centrura; http://www.marinespecies.org/aphia.php?p=taxdetails&id=346053

A. clausi; http://www.marinespecies.org/aphia.php?p=taxdetails&id=149755

A. danae; http://www.marinespecies.org/aphia.php?p=taxdetails&id=346026

A. discaudata; http://www.marinespecies.org/aphia.php?p=taxdetails&id=234125

A. enzoi; http://www.marinespecies.org/aphia.php?p=taxdetails&id=346033

A. fossae; http://www.marinespecies.org/aphia.php?p=taxdetails&id=345933

A. hudsonica; http://www.marinespecies.org/aphia.php?p=taxdetails&id=149751

A. italica; http://www.marinespecies.org/aphia.php?p=taxdetails&id=345934

A. longiremis; http://www.marinespecies.org/aphia.php?p=taxdetails&id=346037

A. margalefi; http://www.marinespecies.org/aphia.php?p=taxdetails&id=346039

A. macropus; http://www.marinespecies.org/aphia.php?p=taxdetails&id=149753

A. negligens; http://www.marinespecies.org/aphia.php?p=taxdetails&id=346030

A. omori; http://www.marinespecies.org/aphia.php?p=taxdetails&id=149752

A. plumosa; http://www.marinespecies.org/aphia.php?p=taxdetails&id=345937

A. teclae; http://www.marinespecies.org/aphia.php?p=taxdetails&id=346041

A. tonsa; http://www.marinespecies.org/aphia.php?p=taxdetails&id=345943

Paracartia grani; http://www.marinespecies.org/aphia.php?p=taxdetails&id=104264

Paracartia latisetosa;
http://www.marinespecies.org/aphia.php?p=taxdetails&id=104265

Pteriacartia josephinae;
http://www.marinespecies.org/aphia.php?p=taxdetails&id=104266

Molecular information

NCBI Nucleotide database: Acartiidae (crustaceans). Available at:
https://www.ncbi.nlm.nih.gov/nuccore/?term=acartiidae

Other useful links

Razouls C., Desreumaux N., Kouwenberg J. and de Bovée F., 2005–2021. Biodiversity of Marine Planktonic Copepods (morphology, geographical distribution and biological data). Sorbonne University, CNRS.
Available at: https://copepodes.obs-banyuls.fr/en/fichefam.php?fam=1

NOAA. COPEPOD: The Global Plankton Database project. Acartiidae. Available at: https://www.st.nmfs.noaa.gov/nauplius/media/copepedia/taxa/T4001907/

8 Terminology and abbreviations

Terminology

Segment Repetitive part of a metameric organization of the body. Sometimes synonym of *somite.*

Somite Segment; one segment can contain two somites (or more) when these are fused together in the adult morphology.

Article A piece of an articulated appendage (antenna or leg). Sometimes appendages have a typical name for their articles (e.g. antennomeres, in Antennulae). As in the case of segment-somite, also in the case of article-antennomeres, an article can be the result of the fusion of two or more antennomeres.

Stage Period/condition of the development of each individual (e.g. egg, larva, juvenile, adult). Each stage can comprise more instars or ages (in the case of Calanoida: six ages in the stage Nauplius, and six ages in the stage Copepodite).

Key to abbreviations

A1	Antennule	**Mxp**	Maxilliped
A2	Antenna	**P1–5**	Thoracic legs 1–5
B1	Coxa	**Re**	Exopod
B2	Basis	**Ri**	Endopod
Mn	Mandible	**PRS**	Prosome
Mx1	Maxillule	**URS**	Urosome
Mx2	Maxilla		

Arabic numerals indicate different PRS and URS segments. The spine and setal formula of the swimming legs is given in the mode of Sewell (1949). The spines (Roman numerals) and setae

(Arabic numerals) are numbered from proximal to distal article on each branch of the limb, and from lateral to medial position on each article, as indicated in the following explanatory scheme:

	B1	B2 (1 article)	Re (3 articles)	Ri (2 articles)
P1	0	1/0-0	I-1; I-1; II, I, 4	0-1; 1-2-3
P2	0	0-0	0-1; 0-1; 0-I-5	0-2; 1-2-4
P3	0	0-0	0-1; 0-1; 0-I-5	0-2; 1-2-4
P4	0	1-0	0-1; 0-1; 0-I-5	0-2; 1-2-3

9 Acknowledgements

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