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New records of *Candonocypris novaezelandiae* (Crustacea, Ostracoda) from Germany, Belgium, England and Tunisia

Burkhard Scharf, Claude Meisch, Isa Schön & Koen Martens

Summary: *Candonocypris novaezelandiae* (Baird, 1843) is widely distributed in New Zealand and Australia. The carapace and the appendages of this ostracod, which is about 1.8 mm long, are briefly described and illustrated. In 1993, the species was for the first time collected in the Lower Rhine Valley in Germany. A list of all the German, Belgian, English, and Tunisian localities that are presently known is given. Recently, this species was also detected in Egypt. The probable dispersal of *C. novaezelandiae* from North Africa to Europe is discussed.

Zusammenfassung: Neue Nachweise von Candonocypris novaezelandiae (Crustacea, Ostracoda) aus Deutschland, Belgien, England und Tunesien. – *Candonocypris novaezelandiae* (Baird, 1843) ist in Neuseeland und Australien weit verbreitet. Der Carapax und die Weichteile dieser etwa 1,8 mm langen Art werden hier beschrieben und detailliert abgebildet. Die Art wurde 1993 erstmalig in Deutschland, am Niederrhein, entdeckt. Eine Liste aller bekannten Funde dieser Art aus Deutschland, Belgien, England und Tunesien wird hier vorgestellt. In den letzten Jahren wurde die Art auch in Ägypten gefunden. Die wahrscheinliche Ausbreitung von *C. novaezelandiae* über Afrika nach Europa wird diskutiert.

1 INTRODUCTION

Ostracoda are small crustaceans whose soft part is totally enclosed within a carapace (or shell) that consists of two mostly calcified valves. Only the tips of the appendages stick out of the carapace when the animals move around or freely swim in the water column. Ostracods are found living in virtually any aquatic environments. Globally, there are around 2100 known species living in non-marine continental waters (Karanovic 2012, Martens & Savatenalinton 2011, Martens & al. 2008), of which 156 have been reported from western and central Europe (Meisch 2000).

Candonocypris novaezelandiae (Baird, 1843) was first described from New Zealand and has since been shown to be widely distributed in both New Zealand (Eagar 1971) and Australia, Tasmania included (Chaplin & Ayre 1989, De Deckker 1981). It has also been recorded from New Caledonia (De Deckker 1983), China (Yu & al. 2010), Japan (Okubo 1975), South Africa (Martens 2001), Egypt (Ebtesam 2010) and Spain (Escrivà & al. 2014).

In the present study, we present a brief redescription of *C. novaezelandiae* (Baird, 1843). Recent findings of this species in Europe lead us to investigate the distribution of *C. novaezelandiae*.

2 METHODS

The samples from Germany and Tunisia were collected using a hand net with 200 µm mesh size and were immediately sieved with 5 mm mesh size to eliminate the coarse sediment. The ostracods were separated from the sediment using a pipette and preserved in 96% ethanol. The samples collected by B. Scharf are stored in his collections. The valves were cleaned for the SEM by overnight maceration in 7% KOH (Matzke-Karasz 1995). For the Belgian sample, ostracods were kept alive for culturing.

The temperature was measured with a standard mercury thermometer, the salinity with the refractometer REF 211 (Arcarda® GmbH), the conductivity with WTW LF 90SE, and the geographic coordinates were taken with a Garmin GPSmap 76 (WGS 84) or checked in Google Earth.

The chaetotaxic scheme is after Broodbakker & Danielopol (1982), as modified for the antenna by Martens (1987) and for the second and third thoracopods (L6, walking leg and L7, cleaning leg) by Meisch (1996). For a review of the scheme see Meisch (2000).

To carry out the taxonomy and review of papers that include the species dealt with here, the "Kempf Database Ostracoda" (Kempf 1980, 1991, 1997, 2002, 2006, 2013) was extensively used.

Abbreviations: LV = left valve, RV = right valve, A1 = antennule, A2 = antenna, Md = mandibula, Mx1 = maxillula, L5 = T1, first thoracopod, maxilliped, L6 = T2, second thoracopod, walking leg, L7 = T3, third thoracopod, cleaning leg, SEM = scanning electron microscope.

3 RESULTS

3.1 Records

The list presents all known records of *Candonocypris novaezelandiae* in Germany, Belgium, England and Tunisia.

Germany: 1. Stream Fossa Eugeniana; 51°31'21" N; 6°33'30" E, conductivity in 1993: 5,548 (2,800–11,080) µS cm^{-1} (n = 8), pH: 7.5–7.8, measured by U. Kosmac. October 12, 1993; leg. U. Kosmac, det. B. Scharf, 2 living females, 2 empty carapaces, 5 valves; July 11, 2011; leg. U. Kosmac, det. B. Scharf: 5 empty carapaces, 6 valves; July 18, 2011; leg. U. Kosmac, det. B. Scharf: 1 empty carapace. – **2.** Flood plain of the River Rhine; 51°34'46" N; 6°35'09" E; pond, July 19, 2002; leg./det. U. W. Abts: 50 living animals, c. 1000 empty carapaces or valves. – **3.** Flood plain of the River Rhine; 51°22'25" N; 6°40'29" E; harbor of the River Rhine 'Die Roos', August 17, 2002; leg./det. U. W. Abts: 1 empty carapace. – **4.** Flood plain of the River Rhine; 51°42'43" N; 6°24'41" E; shallow pond near the River Rhine, September 9, 2002; leg./det. U. W. Abts: c. 300 empty carapaces. – **5.** Flood plain of the River Rhine; 51°42'39" N; 6°24'51" E; pond near the River Rhine, September 14, 2008; leg./det. U. W. Abts: 3 empty carapaces. – **6.** 51°01'16" N; 6°34'01" E; pond near a reservoir, April 5, 2009; leg./det. U.W. Abts, 2 empty carapaces. – **7.** 51°03'02" N; 6°44'34" E; artificial pond near golf place, April 26, 2009; leg./det. U. W. Abts: 4 living animals, c. 100 empty carapaces and valves. – **8.** Flood plain of the River Rhine; 51°31'19" N; 6°36'09" E; pond near the River Rhine, May 5, 2009; leg./det. U. W. Abts: 1 empty carapace, 2 valves. – **9.** Flood plain of the River Weser; 53°11'22"N; 8°30'59" E; loam pit close to the River Weser; December 13, 2009; conductivity 1,277 µS cm^{-1}, leg./det. B. Scharf: 1 living female; September 4, 2010; conductivity 1,260 µS cm^{-1}, leg./det. B. Scharf: 1 empty carapace.

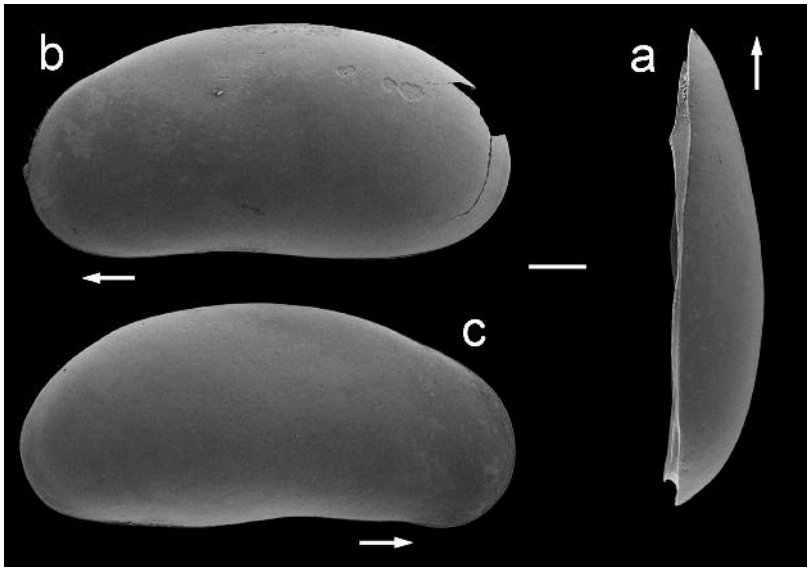

Fig. 1: *Candonocypris novaezelandiae*, female. a) RV, dorsal view, length 1.76 mm, Germany, sample site 1, Oct. 12, 1993; b) LV, external view, length 1.74 mm, Tunisia, sample site 1; c) RV, external view, length 1.80 mm, same animal as b. Arrows point to the anterior. Scale bar: 200 µm.

Belgium: 1. Flanders (North Belgium), Hollandersgatkreek, brackish lake near St. Laureins, 51°15'58" N; 3°31'52" E; conductivity 3,440 µS cm^{-1}; sampled July 17 2008 without living specimens. Afterwards, kept in culture when living specimens appeared after December 2009; leg. I. Schön & K. Martens/det. R. Matzke-Karasz, living specimens in cultured samples.

England: 1. The Great Deep, Thorney Island (Chichester Harbour), 50°49'55" N; 0°55'31" W; living adult female specimens collected by Martin Willing in 2008, subsequently identified by John Whittaker and David J. Horne. The Great Deep is a channel formerly separating Thorney Island from the mainland but now cut off from the tidal estuary of Chichester Harbour by embankments and sluices at both ends; it now contains fresh to slightly brackish water [associated ostracods include candonids and *Cyprideis torosa* (Jones, 1850)].

Tunisia: 1. Reservoir near Enfidha, 36°09'23" N; 10°12'54" E; salinity 1 ‰, March, 27, 2011, leg./det. B. Scharf: 2 valves. – **2.** Reservoir, 37°12'33" N; 9°40'09" E; salinity 1 ‰, March, 28, 2011, leg./det. B. Scharf: 1 living female, 5 larvae, 2 empty carapaces. – **3.** Stream, 37°11'45" N; 9°35'09" E; salinity 4 ‰, March, 28, 2011, leg./det. B. Scharf: 1 living female, 1 valve. – **4.** Reservoir, 37°11'49" N; 09°24'06" E; salinity 1 ‰, March, 28, 2011, leg./det. B. Scharf: 2 living females, 5 juveniles, 2 juvenile valves. – **5.** Small, fast flowing stream, 36°49'56" N; 9°56'50" E; salinity 6 ‰, March, 29, 2011, leg./det. B. Scharf: 1empty juvenile carapace, 1 juvenile valve.

3.2 Taxonomy

Candonocypris novaezelandiae (Baird, 1843) belongs to the subphylum Crustacea Brünnich, 1772, class Ostracoda Latreille, 1802, order Podocopida Sars, 1866, family Cyprididae Baird, 1845, subfamily Herpetocypridinae Kaufmann, 1900, and the genus *Candonocypris* Sars, 1894 with the type species *Candonocypris candonioides* (King, 1855) Sars, 1894 (Horne 2005, Martens & Savatenalinton 2011). The synomyms are: *Cypris Novae Zelandiae* n. sp. Baird, 1843, *Cypris candonioides* n. sp. King, 1855, *Herpetocypris stanleyana* (King) Sars, 1889 (Fide Sars 1894), *Candonocypris candonoides* (spelling error) Sars, 1894, *Candonocypris assimilis* n. sp. Sars, 1894, *Candonocypris novaezelandiae* n. comb. Eagar, 1971.

We here briefly describe and illustrate the animals of *C. novaezelandiae* collected by one of us (B. Scharf) in the Lower Rhine Valley and the Weser region in Germany and in Tunisia (Figs. 1–4). No taxonomically significant differences, neither in the carapace nor the appendages, were found. Only the females are described here, no males having thus far been found outside Australasia.

Carapace elongated in lateral view, with some variation in shape: dorsal margin evenly rounded

with the greatest H approximately situated at mid-length or dorsal margin more distinctly arched with the greatest H being located behind mid-length. Carapace laterally moderately compressed in dorsal view, the RV markedly overlapping the LV in front, moderately so at the posterior end (Figs. 1 & 2).

Valve surface smooth. Central muscle scars distinctly situated in front of valve mid-length. LV and RV asymmetrically built. LV: inner calcified lamella anteriorly broad, with a short inner list that vanishes anteriorly; posterior inner lamella narrow, postero-ventrally with an internal list carrying a small node followed by a row of c. 14 tiny pustules (Fig. 2g) and a similar node in the anterior-ventral region (Fig. 2f). RV distinctly longer than LV (e.g., 1.80 mm versus 1.74 mm). Anterior end of RV: selvage strikingly displaced inwards, overlapped with a very prominent flange; a row of setae set at the 'outer' base of the selvage; posterior marginal zone: calcified inner lamella narrow. Size: 1.80 mm (average); Germany, Lower Rhine Region: 1.75–1.93 mm, $n = 17$; Germany, floodplain of the Lower Weser: 1.77 mm, $n = 2$; Tunisia: 1.79 mm (average), 1.75–1.86 mm, $n = 10$. Colour: green. A1: 7-segmented; Rome organ and Wouters organ not seen. A2: Natatory setae approximately extending to the middle of the long terminal claws. Mandibular palp as in Fig. 4a. Mx1: Both teeth bristles („Zahnborsten") of third masticatory process smooth; terminal palp segment distally slightly enlarged, with 6 apical setae. L5: respiratory plate with 6 filaments. L6: 5-segmented; setae d1 and d2 subequal in length. L7: 4-segmented; penultimate segment with 2 f-setae. Uropod: chitinous attachment with a basal triangle; uropodal ramus posteriorly with indistinct groups of tiny setulae.

3.3 Remarks

The basal chitinous triangle of the uropodal ramus of *C. novaezelandiae* is a differentiating (diagnostic) feature of the entire subfamily Herpetocypridinae (Fig. 4g). The presence of two 'f' setae on the cleaning leg (Fig. 4f) is a unique character of the genus *Candonocypris* within the Herpetocypridinae.

The carapaces and valves of the animals from both Germany and Tunisia described here rather perfectly fit those recently illustrated in the SEM by Valls & al. (2013) and Escrivà & al. (2014) from Spain. In particular, we confirm the presence of a row of tiny pustules on the inner postero-ventral margin of the LV, which was first described by Valls & al. (2013).

The poorness of Baird's (1843) original description of *Candonocypris novaezelandiae*, without any accompanying illustration, explains at least part of the confusion that has surrounded the taxonomy of this species over more than one century.

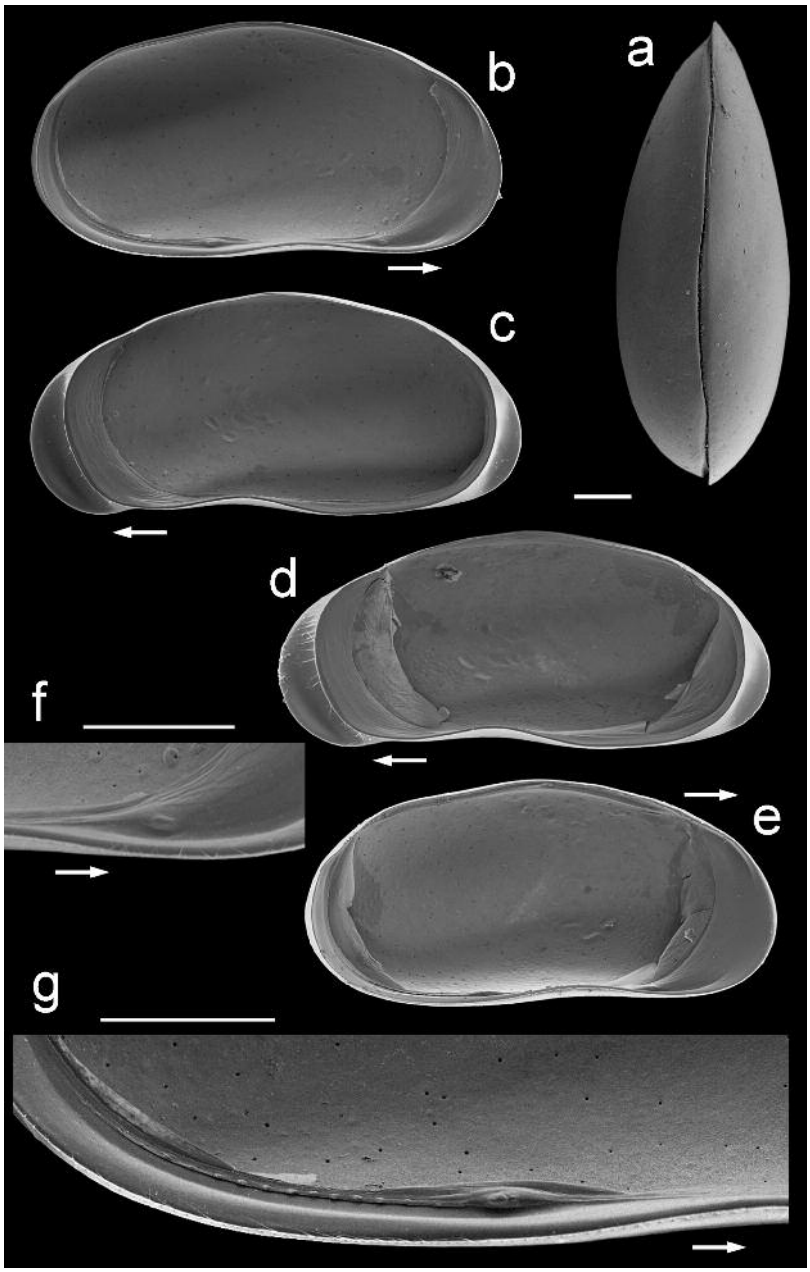

Fig. 2: *Candonocypris novaezelandiae*, female. a) carapace, dorsal view, length 1.72 mm; Germany, sample site 1, Oct. 12, 1993; b) LV, internal view, length 1.72 mm; Germany, sample site 1, Oct. 12, 1993; c) RV, internal view, length 1.80 mm; same animal as b; d) RV, internal view, length 1.77 mm, Germany, sample site 9, Dec. 13, 2009; e) LV, internal view, length 1.68 mm, same animal as d; f) anteroventral LV margin (digitally enlarged from b); g) posteroventral LV margin (digitally enlarged from b). Arrows point to the anterior. Scale bars of all figures: 200 µm.

The genus *Candonocypris* contains 21 nominal extant species (Kempf 1980, 1997) of which 12 or less are currently retained as valid (Karanovic 2012, Martens & Savatenlinton 2011).

We accept the synonyms proposed by De Deckker (1981: 53) and Eagar (1971, 1994) for *C. novaezelandiae*, i.e. *C. candonioides* and *C. assimilis*. De Deckker (1981) points out that *C. novaezelandiae* comes with two morphs: the 'typical', or *C. novaezelandiae* morph, which is larger (c. 1.80–

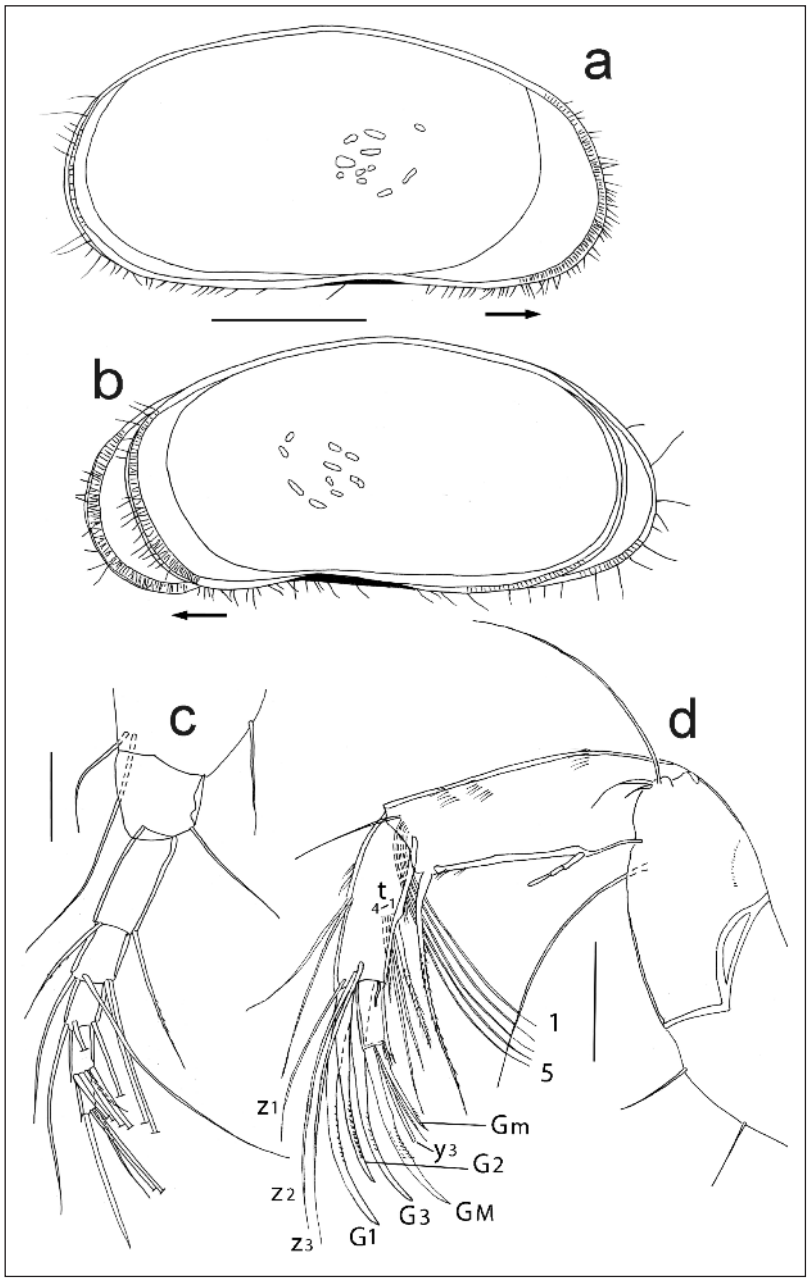

Fig. 3: *Candonocypris novaezelandiae*, female. a) LV, internal view, length 1.72 mm, Germany, sample site 1, Oct., 12, 1993; b) RV, internal view, length 1.80 mm, the same animal as in a; c) A1, Tunisia, sample site 2; d) A2, Tunisia, sample site 4. Scale bars of a and b: 500 µm, and these of c and d: 100 µm.

1.90 mm), the dorsal margin is distinctly arched, with the greatest H situated behind mid-length; the *assimilis* morph is smaller (c. 1.50–1.60 mm), the dorsal margin of its carapace is rather evenly rounded, with the greatest H approximately situated at mid-length.

Chaplin (1992) similarly reports on the occurrence of two morphs in New Zealand: a large green (*C. novaezelandiae*) and a small brown (*C. assimilis*) morph; individuals with transitional carapaces were found. The animals seen by us rather belong to the 'typical' (*C. novaezelandiae*) form.

The animals collected by one of us (B. Scharf) in both Germany and Tunisia possess A2 natatory setae that reach approximately to mid-length of the long terminal A2 claws. Animals identified as belonging to *C. novaezelandiae* and bearing similarly long natatory setae were described for animals coming from New Zealand, Japan and China (Eagar 1994, Okubo 1975, Yu & al. 2011), and also Spain (F. Mesquita-Joanes, pers. comm.). However, a number of other authors mention A2 natatory setae which are distinctly shorter, extending at the utmost to the distal end of the penultimate segment, for individuals collected in New Zealand, Australia and Egypt (De Deckker 1981, Ebtesam 2010, Hussainy 1969, Sars 1889, 1894). This difference has so far not been pointed out in the literature and its taxonomic significance appears unclear at the present state of knowledge. De Deckker (1981) notes that adults have never been seen to swim, while juveniles are good swimmers, having natatory setae much longer than the adults. If this would be true, it is to our best knowledge, a unique case of reduction in length of those setae during postembryonic development in any cypridid lineage.

4 DISCUSSION

Males of *Candonocypris novaezelandiae* were found only in Australasia (mainly New Zealand and Australia (Chaplin & Ayre 1989, De Deckker 1983) and the species was also recovered there in Pleistocene sediments (Eagar 1995) while it was never recorded in European Quaternary sediments (Griffiths 1995). The question arises how and by which means *C. novaezelandiae* has reached Europe and Northern Africa. Valls & al. (2013) suggested that North Africa, where the species had previously been recorded from Egypt (Ebtesam 2010) may have served as a stepping-stone for colonization of water bodies in Spain via migrating birds and/or human activity. There have been other studies providing genetic evidence for long-distance dispersal of non-marine ostracods across Europe (Bode & al. 2010, Schön 2007) and between Europe and Australia (Koenders & al. 2010), respectively. Horne & Smith (2004) reported another example of a non-marine ostracod species, *Potamocypris humilis* (Sars, 1924), co-occuring in Africa and the UK, which the authors also explained by long distance dispersal. The records of *C. novaezelandiae* from Tunisia presented herein, together with those formerly known from Egypt (Ebtesam 2010), tend to indicate that the species currently has a wide distribution in North Africa. This strengthens the hypothesis that the Spanish populations descend from those present in North Africa. The German, Belgian and English populations would either originate from Spain or directly from North Africa. The passive introduction of the species into Central and Western Europe by birds appears most likely, the more so as both the known German as well as the Belgian populations are located along the migrating routes of many water birds (the Lower Rhine valley and the Lower Weser region in Germany and Flanders in North Belgium

being close to the North Sea). Finally, we hypothesize that additionally to Spain, *C. novaezelandiae* has most likely already colonized other areas in southern Europe, as for example southern France, Italy, and the Balkans.

From our limited data, it furthermore seems that *C. novaezelandiae* occurs in a range of different habitats and salinities. If it is indeed a species with wide ecological tolerances, this feature would further contribute to its success as invader.

Additionally to *C. novaezelandiae* there are other non-native freshwater Ostracoda in Germany and Europe in general. Three examples are briefly discussed here:

In 1949, *Isocypris beauchampi* (Paris, 1920), which is African in origin (Meisch 2000), was collected for the first time in Germany, i.e. in the River Eider near the North Sea (Herbst 1951). *I. beauchampi* is about 1.2–1.4 mm in size (Meisch 2000) and it is unlikely that the ostracod researchers would have overlooked this relatively large species in Germany before 1949. *I. beauchampi* has since been reported from across Germany multiple times (Brandorff & al. 2013, Fuhrmann 2012, Herbst 1951, 1965, Hollwedel & al. 1988, 1994, 2008, Nüchterlein 1969, Scharf 1988, 1998, Wendling & Scharf 1992; Lake Constance 2012, F. Viehberg, pers. comm.). In the collections of B. Scharf there are 23 records of *I. beauchampi* from Germany in various habitats, namely ponds, lakes, and an oxbow lake of the Upper Rhine. The species was collected throughout the year. The conductivity of the majority of localities with *I. beauchampi* varied between 100 and about 1400 µS cm^{-1}, which indicates that the species, though preferring limnic habitats, tolerates oligohaline conditions. *I. beauchampi* is found in southern England in the 1960s (D. Horne, pers. comm.) and is meanwhile distributed in many countries of Europe as well as North and South America (Meisch 2000).

Potamocypris humilis, which is in South Africa in origin, is meanwhile also found in Finland (Hagermann 1967, Purasjoki 1948), in United Kingdom (Horne & Smith 2004), and in the Baltic Sea (Frenzel & al. 2010).

Fabaeformiscandona subacuta (Yang, 1982), which is widespread in Eastern Asia, Japan and Australia (Escrivà & al. 2014) is another 'alien' species probably recently introduced into Europe, where it is currently only known from eastern Spain and where it is considered as an invasive species (Escrivà & al. 2012, 2014). The latter authors suggest that the species arrived there due to human activities, perhaps via inter-continental shipping. *F. subacuta* closely resembles *Fabaeformiscandona holzkampfi* (Hartwig, 1900) with which it has been confused (Escrivà & al. 2014) and we therefore suspect that it has already gained a wider distribution in Europe than the records in Spain would indicate.

We suggest that in the future special attention should be paid to both *C. novaezelandiae, P. humilis* and *F. subacuta* in order to monitor the development of their invasive distribution in Germany and Europe in general.

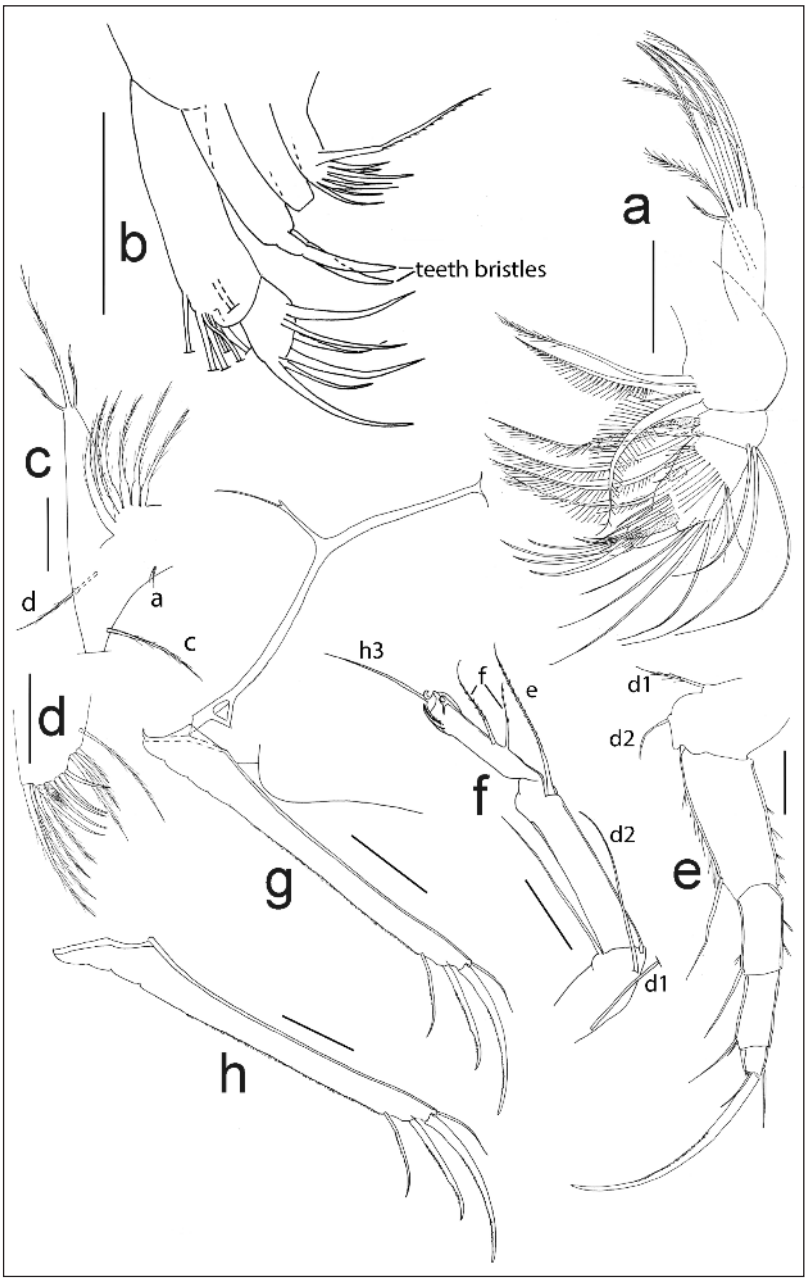

Fig. 4: *Candonocypris novaezelandiae,* female. a) Md palp, Germany, sample site 9, Dec., 13, 2009; b) Mx1, Germany, sample site 9, Dec., 13, 2009; c) L5, posterior part, Germany, sample site 9, Dec., 13, 2009; d) L5, anterior part, Germany, sample site 1, Oct., 12, 1993; e) L6, Tunisia, sample site 2; f) L7, Germany, sample site 9, Dec., 13, 2009; g) genital lobe and right uropod and uropodal attachment, Germany, sample site 9, Dec., 13, 2009; h) left uropod, Germany, sample site 9, Dec., 13, 2009. Scale bars = 100 µm.

5 CONCLUSIONS

1. The original distribution area of *Candonopsis novaezelandiae* is most probably in Australasia, where the species is widespread, where both fe-

males and males are known to occur, and where the species was recovered already in Pleistocene sediments. – **2**. All-female populations recorded from Japan, China, South Africa, North Africa (Egypt and Tunisia), and Europe (Spain, Germany, Belgium, and the UK) probably arrived there via passive dispersal by birds and/or human activity. – **3**. There is a need for the taxonomic revision of the species of the genus *Candonocypris*, because two carapace morphs and different lengths of the natatory setae of the antenna could be found in the different populations of this species.

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