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The worldwide range of the Charophyte species native to Germany

Abstract

Based on extensive evaluations, the worldwide distributions of the 36 Charophyte species native to Germany are presented. Some of these species are distributed almost worldwide (e.g. *Chara braunii*, *C. vulgaris*, *Nitella hyalina*), while others have much smaller ranges. *Chara filiformis* for example is restricted to a small part of continental Europe. For many species comments are made to explain the species concept used or to give hints about doubtful data.

Keywords: Plant geography, Characeae, Charophytes, range-maps, *Chara*, *Lamprothamnium*, *Lychnothamnus*, *Nitella*, *Nitellopsis*, *Tolypella*

Zusammenfassung: Areale der in Deutschland heimischen Characeen-Arten.

Auf der Grundlage umfangreicher Recherchen werden die weltweiten Areale der in Deutschland vorkommenden 36 Characeen-Arten dargestellt. Von diesen Arten sind einige (z. B. *Chara braunii*, *C. vulgaris*, *Nitella hyalina*) fast weltweit verbreitet, andere haben deutlich kleinere Areale. So ist z. B. *Chara filiformis* auf kleine Teile Europas beschränkt. Zu einer ganzen Reihe von Arten werden Kommentare geben. Diese erläutern die verwendeten Artumgrenzungen oder geben Hinweise zu fraglichen Angaben.

1 Introduction

In recent decades and after a phase of stagnation in Germany, interest in the Characeae has markedly increased. The Habitats Directive 92/43/EC (EC1992) and the Water Framework Directive 2000/60/EC (EC 2000) of the European Union have intensified this process.

Because of their size and their complex structure, the Charophytes are morphologically clearly distinguished from most other groups of Algae. The results of genetic investigations show that they are more closely related to the Mosses and higher plants rather than to the other algae (Qui 2008). For that reason, most of the

people who are studying these plants are higher plant-botanists rather than phycologists. A consequence of this is that the editors of one of the most important vascular plant floras of Germany, the Rothmaler series (JÄGER 2011, JÄGER et al. 2013) have suggested the inclusion of the Characeae into this flora.

The worldwide distribution range of each species is traditionally described by range formulae in the Rothmaler series. The distribution limits of all German Charophyte species were investigated to support the global distribution limits. A revision of the literature (overview in VAN RAAM 2004) has shown that range-maps are published for only a few species. Furthermore, the existing range-maps are mostly some decades old and, therefore, do not consider the current knowledge and new records.

2 Material and methods

The nomenclatural and taxonomic base used follows the Arbeitsgruppe Characeen Deutschlands (2016). The aim was to identify the worldwide range of all 36 species of Characeae recorded in Germany as exactly as possible. This was done by extensive literature studies (see literature). Where there were existing modern overview works for single countries these were preferred. However, such overviews are only available for some European and very few other countries. From many other parts of the world there are only, if any, scarce publications. Only a few reviews of herbarium material were made. However, in many of the publications used such reviews are one of the basic sources. In addition, scans of the herbarium sheets from many North American herbaria available in the internet over the “Macroalgal Herbarium Portal” were used to confirm and complete literature data. Broad, inaccurate information like “Siberia”, records only for a whole country or dots without sources in published maps like that of CORILLION (1957) were ignored intentionally.

The extremely wide species concept of WOOD (1965) brings big problems with usage of names in published distribution data. Often, but not in every case, it is obvious in the publications in which sense/extent the names of the species are used. The assignment of records to the species names in the way used by the German authors (Arbeitsgruppe Characeen Deutschlands 2016) was only done if it was certain or very likely. But it was not possible in all cases to clarify which species concept laid behind the names used, whether the usage applied here or that of WOOD (1965). So, some uncertain records still remain unresolved.

Based on this information, it was possible to get a fairly complete picture of the existing records for the distribution of the Charophyte species. But it is important to be aware of the gaps in this knowledge in many regions. The lowest level of knowledge is in many parts of Africa except for the Mediterranean coast. But many of the German species do not extend here and the impact on the range-maps should be minor. Another problematic area is the northern part of Siberia and also of Canada where there are only a few published records. The activities of R. ROMANOV and others has markedly increased the knowledge in recent years but the range borders here are still rough approximations.

All of the identified distribution points or information were brought into a world map in a geographic information system (Quantum-GIS). From this, the resulting shapes of the distribution area of each species were generated. Temporal differentiation of the records could not be made because actual information from many parts of the world are lacking.

3 Results

The range areas are shown with stripes and without surrounding shape-lines to reflect the uncertainty of the borders.



Fig. 1 *Chara aculeolata*



Fig. 2 *Chara aspera*



Fig. 3 *Chara baltica*



Fig. 4 *Chara baueri*



Fig. 5 *Chara braunii*



Fig. 6 *Chara canescens*



Fig. 7 *Chara connivens*



Fig. 8 *Chara contraria*



Fig. 9 *Chara filiformis*



Fig. 10 *Chara globularis*



Fig. 11 *Chara hispida*



Fig. 12 *Chara horrida*



Fig. 13 *Chara papillosa*



Fig. 14 *Chara strigosa*



Fig. 15 *Chara subspinosa*



Fig. 16 *Chara tenuispina*

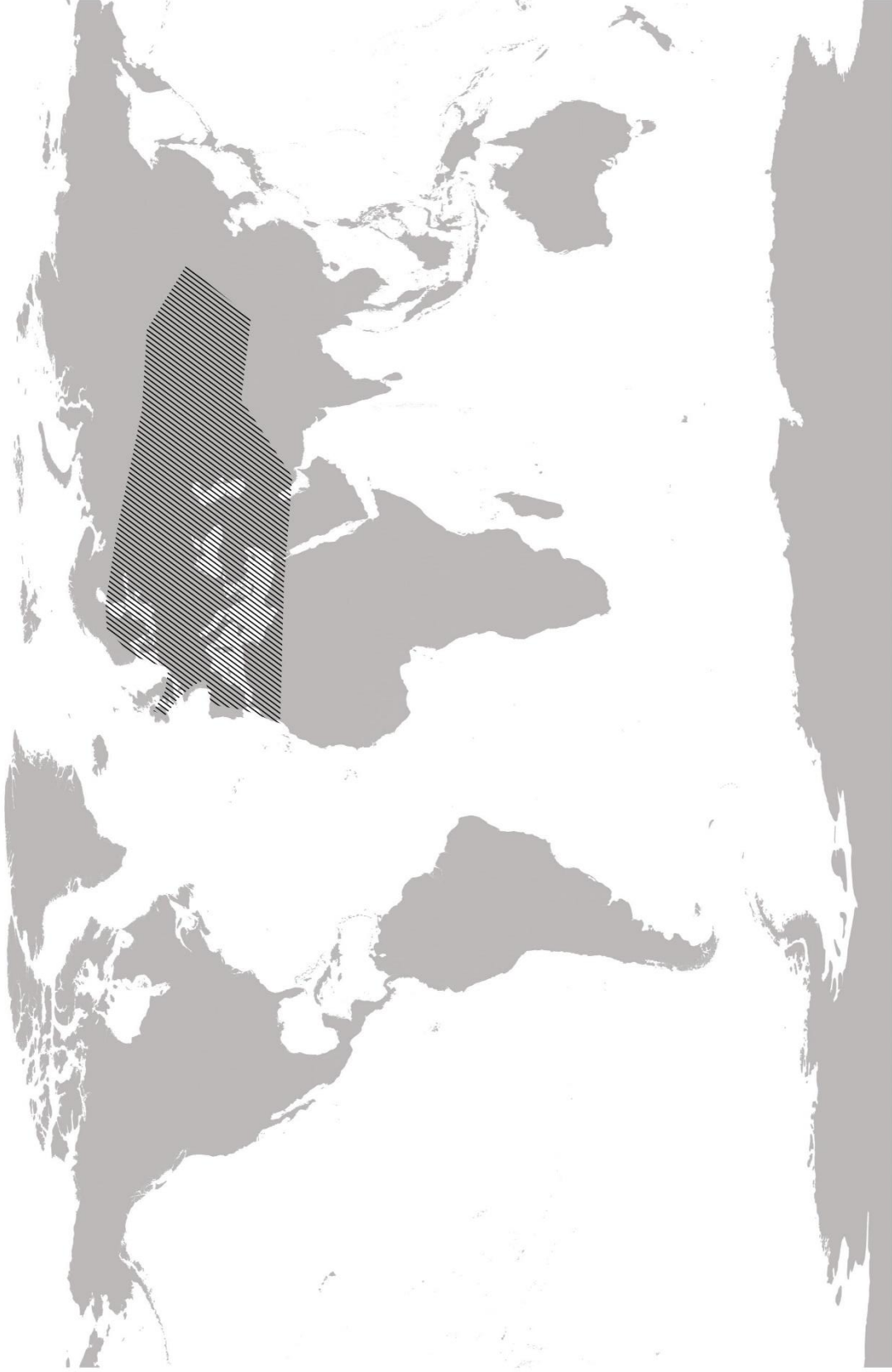


Fig. 17 *Chara tomentosa*



Fig. 18 *Chara virgata*



Fig. 19 *Chara vulgaris*



Fig. 20 *Lamprothamnium papulosum*



Fig. 21 *Lychnothamnus barbatus*



Fig. 22 *Nitella capillaris*



Fig. 23 *Nitella confervacea*



Fig. 24 *Nitella flexilis*



Fig. 25 *Nitella gracilis*

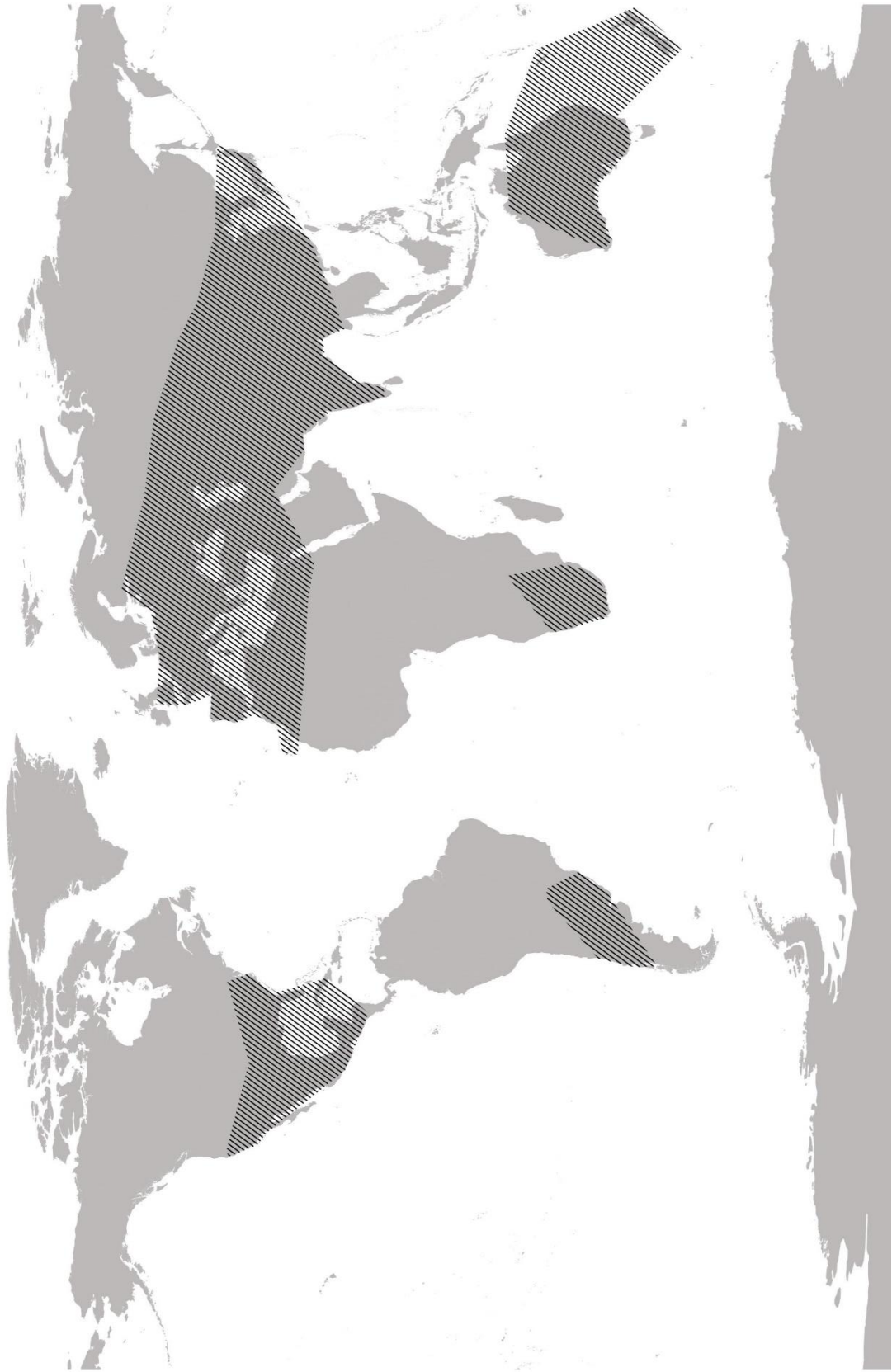


Fig. 26 *Nitella hyalina*



Fig. 27 *Nitella mucronata*



Fig. 28 *Nitella opaca*



Fig. 29 *Nitella syncarpa*



Fig. 30 *Nitella tenuissima*



Fig. 31 *Nitella translucens*



Fig. 32 *Nitellopsis obtusa*



Fig. 33 *Tolypella glomerata*



Fig. 34 *Toypella intricata*



Fig. 35 *Tolypella nidifica*



Fig. 36 *Tolypella prolifera*

4 Discussion

For some species some notes are necessary to aid the understanding of the maps or to explain the classification of records that are uncertain.

Chara aculeolata KÜTZ. in RCHB. (= *C. polyacantha* A. BRAUN): Within the species group around *C. aculeolata* there is considerable confusion. There exist at least five names (*C. aculeolata*, *C. intermedia*, *C. papillosa*, *C. pedunculata* KÜTZ. and *C. polyacantha*) which are used in different or even contradictory ways. Often these species were not separated and also the delimitation from *C. hispida* is not clear in some cases. As a result, there is significant uncertainty with the distribution area.

Chara aspera WILLD.: The taxon *C. curta* NOLTE ex KÜTZ. is sometimes treated as a separate species but is here included in *C. aspera*. However this does not significantly affect the range of *C. aspera* because *C. aspera* s.str. is found in almost all regions with *C. curta*. A similar case is *Chara galioides* DC. It is not included in *C. aspera* here but its inclusion would have only very little impact on the range of *C. aspera* s.str.

Chara baltica (HARTMAN) BRUZELIUS: This name is applied without doubt only to the plants from the Baltic Sea and adjacent areas. Whether all of the so called plants from around the Mediterranean Sea, from Greenland (LANGANGEN 2007), the Black Sea (CARAUS 2012) and the Gulf of Persia (ARNAU 2014) belong to this species is not certain (SCHUBERT et al. 2016a). But there are genetically proved records at least from Sardinia (BECKER pers. comm.). Even more uncertain is the status of the records from central and eastern Asia and southern America.

Chara baueri A. BRAUN: This species is mainly known from a few populations in eastern Germany and western Poland. Beside these there are only single records recently discovered in the Volga-region (КЛИНКОВА & ЖАКОВА 2014) and from Kazakhstan (ROMANOV & KIPRIYANOVA 2010). Furthermore a herbarium sheet exists with plants from south Sweden. The records from Schwerin in Germany and from Austria are uncertain. The plants from Australia sometimes listed as a forma under *C. baueri* and sometimes as a forma under *C. braunii* C. C. GMELIN (e.g. WOOD 1965) are regarded here as a separate species, *C. muelleri* (A. BRAUN) F. MUELL. (see CASANOVA 2014).

Chara canescens LOISEL.: In this dioecous species, only the female plants are widespread. The records from central North America are of monoecious plants (WOOD 1965) and therefore probably belong to another species and not to *C. canescens* in our sense.

Chara filiformis A. BRAUN in HERTSCH: The appearance in the Borkener See in Germany lies in a former coal-mining area (KORTE et al. 2010) far away from the nearest natural populations and is therefore considered as a synanthrope. The record from central Asia (MIGULA 1904 as *C. jubata* A. Br.) should needs to be proofed.

Chara globularis THUILL.: Between *C. globularis* and *C. virgata* KÜTZ. there exist various intermediate forms. For that reason these two species are not differentiated in a few publications (e.g. CIRUJANO et al. 2008). However, *C. globularis* is widely distributed and in most regions it is much more frequent. Probably, there will be only a few areas where *C. virgata* is the only species present and the lack of differentiation will probably not markedly influence the range-map of *C. globularis*.

Chara hispida L.: The type of *C. hispida* in the LINNÉ-Herbaria belongs to *C. aspera* WILLD. In this sense, these names have been used for almost 200 years. In order to avoid ambiguity, VAN RAAM (1998) used the name *C. major* HY for this taxon.

However, there is a formally accepted proposal for preservation of the well-established meaning of the name *C. hispida* (GREGOR et al. 2014) and this is the name used here. The records from the northwest part of Russia need to be checked according to ROMANOV et al. (in print).

Chara horrida WAHLST.: The record from the Black Sea (BORISOVA & TKATSCHENKO 2008) belongs probably to *C. baltica* (N. STEWART and R. ROMANOV, pers. comm.). It is unlikely that the record from Hungary (FILARSZKY 1893) really belongs to this strictly marine species. For that reason, this record is ignored here.

Chara papillosa KÜTZ. (= *C. intermedia* A. BRAUN): In Germany, there are two taxa included under this name (SCHUBERT et al. 2016b), one, which prefers fresh and one which prefers brackish water. Also sometimes the differentiation of this species from *C. baltica* and *C. aculeolata* (see above) is very difficult (SCHUBERT et al. 2016a). Furthermore, the use of these names is full of confusions. For that reason, many published records are uncertain. In particular the records from South America (ALLEN 1940, HORN AF RANTZIEN 1949) need to be confirmed. CIRUJANO et al. (2007, 2008) give the name *Chara intermedia* A. BRAUN as a synonym under the name *Chara hispida* var. *major* (HARTMAN) R. D. WOOD. The picture on page 64 in CIRUJANO et al. (2008) shows plants that seems to belong to *C. hispida* L. So for the records from Spain, it is unclear to which species they belong in the sense of Arbeitsgruppe Characeen Deutschlands (2016). Also KRAUSE (1997), who visited the Iberian Peninsula several times, gives no record for *Chara papillosa* from there. The records of CIRUJANO et al. (2007, 2008) and ARNAU (2014) were, therefore, not included into the map of *C. papillosa* but it is possible that it does occur there.

Chara strigosa A. BRAUN: Sterile plants are sometimes difficult to differentiate from *C. aspera*. The ecological conditions of the Dnestr region (Moldova) (Anonymous 2014, ROMANOV et al. 2014a) are very different from the typical habitats of this species, which is otherwise restricted to higher mountains and boreal regions. This record of *C. strigosa* therefore needs confirmation.

Chara subspinoso RUPR. [= *C. rudis* (A. BRAUN) LEONH.]: One of the most famous Characeae phycologist of Germany W. KRAUSE had problems with differentiating the pair *C. subspinoso* and *C. hispida*. Many wrongly determined herbaria sheets show this clearly. Because of his authority many other people have accepted these erroneous determinations. For that reason, there exist a many wrong or doubtful data in Germany. The record in Czech south of the Erzgebirge (CAISOVA & GABKA 2009) lies also far away from the next confirmed appearances in the Donau valley or in north-east Germany and needs to be confirmed.

Chara virgata KÜTZ.: Between *C. globularis* and *C. virgata* there exist various intermediate forms. For this reason, these two species are not separated in a few publications and united under the name *C. globularis*. It is likely that there will be some additional regions where *C. virgata* grows and has not yet been recorded.

Lamprothamnium papulosum (WALLR.) J. GROVES: The records listed by GUERLESQUIN (1992) for China and Korea and by WOOD (1978) and GUERLESQUIN (1992) for South Africa probably do not belong to this species. These plants are most likely to be *Lamprothamnium macropogon* (A. BRAUN) I. L. OPHEL or *L. succintum* (A. BRAUN) R. D. WOOD (VAN RAAM 2012; R. ROMANOV, pers. comm.). The record from Bangladesh (NAZ & DIBA 2012) is more likely to be *Chara braunii* than *L. papulosum* according to the pictures given in this publication (R. ROMANOV, pers. comm.).

Nitella capillaris (KROCK.) J. GROVES & BULL.-WEBST.: Plants from North America were determined as *N. capillaris* by BRAUN (1883), and also by WOOD in his early years

(e.g. 1947, revisions on sheets in the Herbaria of the University of California, Berkeley). About 20 years later, they were redetermined by WOOD (WOOD 1965, CHOUDHARY & WOOD 1973) as *N. flexilis*. CHOUDHARY (in CHOUDHARY & WOOD 1973) then described these plants as *Nitella flexilis* var. *americana*. Reviews of the plants available as scans in the Macroalgal Portal showed that the original determination as *N. capillaris* seems to be correct. The existence of slime around the gametangia and the dioecism makes the determination by CHOUDHARY & WOOD (1973), even in their very broad species concept, not really reproducible.

Nitella flexilis (L.) C. AGARDH: Some of the taxa treated here as species are included within WOOD's broad species concept of *N. flexilis*. Mainly in southern Europe, *Nitella flexilis* and *N. opaca* (C. AGARDH ex BRUZELIUS) C. AGARDH were sometimes united under the name *N. flexilis* sensu Wood (e.g. CIRUJANO et al. 2007). In Greece for example, KOUMPLI-SOVANTZI (1997) lists only *N. flexilis*. However, only *N. opaca* in the strict sense of Arbeitsgruppe Characeen Deutschlands (2016) is known to grow there (U. RAABE pers. comm.). The data of *N. flexilis* from KOUMPLI-SOVANTZI (1997) have, therefore, been transferred to the map of *N. opaca*. For the Iberian Peninsula CIRUJANO et al. (2007) also united *N. flexilis* and *N. opaca* under the name *N. flexilis* and only the data of ARNAU (2014) could be used in the maps of these two species.

Nitella translucens (PERS.) C. AGARDH: The record published by CARAUS (2012) from the Donau delta in Romania and the record from the Southeast Ukraine (BORISOVA 2014) are doubtful. These regions do not have the ecological conditions needed by this mainly oceanic or suboceanic species of soft water. In the past there were sometimes false determinations of *Nitellopsis obtusa* as *Nitella translucens* and this seem to be the most likely confusion. The records from Africa (BRAUN 1883) and from Bangladesh (PAL et al. 1962) are far away from the known range and it seems that nobody has confirmed it since that time. The plants from south India (pictures in SUBRAMANIAN 2002) look quite different to the European plants of these species. A re-examination of the material from these regions is needed. Under *N. translucens* in WOOD (1965) are *N. axillaris* A. BRAUN as a forma and *N. sublucens* T. F. ALLEN as a subspecies. Both are regarded here as separate species and are not included.

Nitellopsis obtusa (DESV.) J. GROVES: For several decades this has been an introduced and expanding species in North America (GEIS et al. 1981, ESCOBAR et al. 2016, ALIX et al. 2017).

Tolypella glomerata (DESV.) LEONH.: The records from south Australia which were based on collections and determinations of R. D. WOOD (WOOD 1965) do not belong to this species according to VAN RAAM (2012).

Tolypella intricata (TRENTEP. ex ROTH) LEONH.: The records from the Leningrad oblast and from the Nenets Autonomous Okrug need to be checked according to ROMANOV et al. (in print).

Tolypella nidifica O. F. MÜLL.: The differentiation of this species from *T. salina* CORILLION is very difficult and also, so far, no genetic differences have been found (P. NOWAK pers. comm.). For that reason it could be useful to include *T. salina* into *T. nidifica*. Although KRAUSE (1997) gives two records of *T. nidifica* from Spain, CIRUJANO et al. (2008) and CIRUJANO BRACAMONTE et al. (2013) list only *T. salina* for the Iberian Peninsula. The inclusion of *T. salina* would enlarge the range of *T. nidifica* onto the Iberian Peninsula.

Tolypella prolifera (ZIZ ex A. BRAUN) LEONH.: The records from South America as *T. prolifera* var. *montevideensis* (ALLEN & HERTER 1934, WOOD 1965) do not belong to this species according to VAN RAAM (2012).

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