**RESEARCH ARTICLE** 



### Solanum jobsonii, a novel andromonoecious bush tomato species from a new Australian national park

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#### Abstract

A new species of *Solanum* from the Australian "andromonoecious bush tomato clade" of *Solanum* subgenus *Leptostemonum* is described. *Solanum jobsonii* Martine, J.Cantley, & L.M.Lacey, **sp. nov.** is part of the *S. eburneum* Symon species group. It most closely resembles *S. eburneum* and *S. watneyi* Martine & Frawley of the northwestern part of the Northern Territory, but is separated geographically from them by the Sturt Plateau. Morphometric analyses show that *S. jobsonii* differs statistically from *S. eburneum*, *S. watneyi*, and *S. diversiflorum* F.Muell. – a similar species in habit and leaf characters – in several key reproductive and vegetative characters. We provide morphometric evidence for the recognition of *S. jobsonii*, a complete description, a table of comparisons within its species group, and a map showing species group distributions. One of the first new species to be described from Limmen National Park (established 2012), *S. jobsonii* is a testament to the value of designating and protecting public lands, as well as supporting science relating to them.

#### **Keywords**

Limmen National Park, Northern Territory, *Solanum watneyi*, *Solanum eburneum*, *Solanum diversiflorum*, *Solanum jobsonii*, Peter Jobson, andromonoecy, national parks, public lands, Australia

#### Introduction

*Solanum* L. is one of the more species-rich Angiosperm genera, with representation on all continents save for Antarctica. In Australia, where upwards of 120 *Solanum* species are known (Symon 1981), members of the group are especially abundant components of disturbance-adapted and fire-tolerant outback plant communities; and a handful of

species have been used for thousands of years by indigenous peoples as "bush tucker" (Peterson 1976, Symon 1981, Doonday et al. 2013).

However, despite the conspicuous nature of the genus in parts of Australia, new species of *Solanum* have continued to be discovered in recent years – especially members of the "spiny solanum" group (*Solanum* subgenus *Leptostemonum* Bitter) in the northern Australian Monsoon Tropics (Brennan et al. 2006, Bean and Albrecht 2008, Barrett 2013, Martine et al. 2013, Bean 2016, Martine et al. 2016a, Martine et al. 2016b).

The "andromonoecious bush tomato clade" is a group of 12 currently recognized species that was recognized by Martine and colleagues based on analysis of ITS (Martine et al. 2006) and trn-KmatK sequence data (Martine et al. 2009). Included in the clade are two morphologically similar species groups, one comprised of *S. chippendalei* Symon, *S. succosum* A.R. Bean & Albr., *S. beaugleholei* Symon, and *S. phlomoides* A.Cunn. ex Benth., and another comprised of *S. eburneum* Symon, *S. watneyi* Martine & Frawley and *S. diversiflorum* F.Muell. Unnamed variants are known to exist within each of these groups that require the collection of more specimens. One of these variants, from the *S. eburneum* group, is described here as *Solanum jobsonii* sp. nov.

Reproductive populations of *Solanum jobsonii* piqued the curiosity of Australian botanists during 2008 and 2010 biodiversity surveys (see Cowie et al. 2011) of the proposed Limmen National Park on the edge of the Gulf of Carpentaria in northeastern Northern Territory. Collections of these plants, initially identified as *S.* aff. *eburneum*, were brought to the attention of the authors by the staff of the Northern Territory Herbarium and inspired a collecting expedition to the recently-designated Limmen NP in 2016. Specimens from this expedition and seed-grown greenhouse plants were used to conduct morphometric comparisons between *S. jobsonii* and the three previously recognized taxa in the *S. eburneum* group. We here contrast both its morphology and distribution with its close relatives, and provide a table of comparisons for members of the *S. eburneum* group.

#### Materials and methods

Based on locality data provided on specimens available at DNA and BUPL herbaria (acronyms according to Index Herbariorum; http://sweetgum.nybg.org/science/ih/), the primary known populations of *S. jobsonii* were visited along the Nathan River Road in Limmen NP. Herbarium specimens, leaf material for future DNA work, and mature fruits were collected. Seeds of the putative new species were removed from fresh fruits, dried, and stored for later use in establishing a greenhouse population.

Plants were grown for use in ex situ morphometric analyses by soaking fieldcollected seeds in 1000-ppm gibberellic acid for 24 hours, then sowing them in a controlled growth chamber environment at Bucknell University (Pennsylvania, USA). Seeds germinated in 2-3 weeks and plants were cultured under Integrated Pest Management conditions. Twenty-six vegetative and reproductive characters were measured across developmental stages. Leaf lobe depths were based on measures from the base of the most deeply cut sinus to the tip of the nearest lobe. All morphological data were then compared against related species collected during the 2016 expedition and specimens examined during visits to the Northern Territory Herbaria at Palmerston (DNA) and Alice Springs (NT).

Comparison statistics were generated using the software package JMP Pro 12 (SAS Institute Inc., Cary, North Carolina, USA). Initial analyses were carried out on the dataset using a one-way ANOVA with Student's t-test mean comparison with P<0.05. A Connecting Letters Report summarizes mean values of each character across the four study taxa (*S. watneyi, S. eburneum, S. diversiflorum, S. jobsonii*) and provided similarity comparisons based on calculated means and tests carried out. This Connecting Letters Report was utilized to investigate individual differences between species before analyzing grouping differences through multivariate morphometric analyses.

Multivariate morphometric analyses were then conducted on the entire dataset for all four species. Principal component analysis (PCA) was used to determine morphological variation pattern groupings among the four taxa. A set of variables was plotted based on corresponding eigenvalues calculated using JMP Pro, representing the original dataset with the greatest variation in a two-dimensional space.

#### Results

The PCA recognized five eigenvalues above a value of 1 and these were used to determine that the data set was in its entirety five-dimensional, with principal components 1 and 2 contributing the greatest amount of variation among the points (56.6% of the variation within the data set). Figure 1 provides both the score plot with each of the data points plotted, as well as the loading plot. The loading plot depicts which characters had the greatest weight in pulling out the points within the score plot to each of their respective quadrants, therefore determining which characters had the greatest influence in delimiting the species. When reading Figure 1, one may mentally superimpose the two plots to view the points and the corresponding vectors whose magnitude represents the associated character's weight in plotting the dataset and grouping of individuals, but as the loading plot is much smaller it is represented as a separate panel to depict species character influence described above.

The PCA score plot based on all measured characters for *S. watneyi*, *S. eburneum*, *S. diversiflorum*, and *S. jobsonii* supports the relative distinctiveness of *Solanum jobsonii* based on character grouping when compared to the other three closely related taxa, although some overlapping with *S. diversiflorum* and *S. eburneum* variants is observed (Figure 1a). The loading plot (Figure 1b) suggests that the depth of lobing in young leaves near the apices of growing shoots (identified in Table 1 as "apical leaves") was the character with the greatest weight pulling *S. jobsonii* in the direction of its respective quadrant.

These results, in conjunction with ANOVA comparisons of each individual character across the four taxa support the hypothesis that *S. jobsonii* is a distinct entity. The addition of student's t-tests also provided a Connecting Letters Report (Table 1). The table is to be read horizontally across each of the four taxa as a means to compare across



Figure 1. Principal components analysis score plot (Fig. 1a, left) and loading plot (Fig. 1b, right) of characters and species in Table 1. Most heavily weighted characters labeled and indicated with red arrows in loading plot. Red triangles = *S. jobsonii*; black crosses = *S. eburneum*; purple circles = *S. diversiflorum*; yellow diamonds = *S. watneyi*. Labels for loading plot are as follows: A Apical leaf depth of lobing B Basal leaf width C Basal leaf depth of lobing D Stem prickle length E Hermaphrodite calyx lobe length
F Staminate calyx lobe length G Basal leaf length H Male corolla diameter I Hermaphrodite corolla diameter J Apical leaf length K Apical leaf surface area L Petiole length M Internode length N Apical leaf width O Plant height P Fruiting pedicel length Q Seed length.

discrete characters. Taxa maintaining separate letter distinctions for any one measured character are recognized as being significantly different from the other three taxa in that character. Nine characters (highlighted in Table 1) meet this criterion for *Solanum jobsonii*, including corolla diameter (in both staminate and hermaphrodite flowers), calyx lobe length, and length of the fruiting pedicel.

Table 2 presents an additional set of non-numerical characters that one can use for drawing distinctions between the four taxa of the *S. eburneum* species group (Table 2).

#### Taxonomic treatment

*Solanum jobsonii* Martine, J.Cantley, & L.M.Lacey, sp. nov. urn:lsid:ipni.org:names:77163784-1 Fig. 2

**Diagnosis.** With affinity to *Solanum eburneum*, *Solanum watneyi*, and *Solanum diversi-florum*, but differing by the involute corolla margins, deeply dissected leaves with 6–12 lobes and smaller creamy-yellow fruits.

**Type.** AUSTRALIA. The Northern Territory: Limmen National Park, on main road, 15°54'47"S, 135°31'43"E, elev. ca. 250 ft, 12 May 2010 (fl, fr), *B. Stuckey & I.D. Cowie 645* (holotype [two sheets]: DNA)

tion (SD), sample size (n), and Connecting Letters Report (CL) which indicates distinctions among species by character. Species not connected by the same letter in a row are significantly different (p < 0.05) for that character. All measurements in cm, except seeds per fruit, seed length and fruit wall width (mm), leaf surface area (cm<sup>2</sup>), and trichome density (per 0.5 cm<sup>2</sup> area). "Apical" refers to leaves near the tips of growing stems, while "Basal" refers to leaves borne on lower portions of the Table 1. Vegetative, floral, and fruiting characters measured for S. watneyi, S. eburneum, S. diversiflorum, and S. jobsonii with associated mean (M), standard deviastems. The nine characters found to be significantly different in *S. jobsonii* when compared to the other three taxa are in bold.

											2				:	
		S. wa	tneyi			S. ebur	meum			S. divers	iftorum			S. job	inni	
Character	Μ	SD	u	CL	Μ	SD	u	CL	Μ	SD	u	CL	Μ	SD	u	CL
Stem prickle length	0,26	0,26	25	BC	0,40	0	16	Α	0,22	0,09	30	С	0,29	0,12	54	В
Internode length	4,01	0,98	25	Α	2,16	0,67	16	в	2,23	0,91	30	В	1,48	0,51	54	υ
Petiole length	3,36	3,36	25	Α	2,68	0,80	16	в	1,03	0,53	30	C	0,82	0,39	54	C
Apical leaf length	12,39	2,50	25	Α	11,32	0,10	16	Α	2,66	0,77	25	С	5,13	1,39	35	в
Apical leaf width	2,47	0,65	25	Α	1,41	0,41	16	В	1,61	0,41	25	В	1,48	1,17	35	В
Basal leaf length	16,80	3,85	25	A	13,66	1,83	16	В	5,80	1,98	25	D	9,18	1,87	29	C
Basal leaf width	3,97	1,15	25	в	2,03	0,88	16	D	3,24	0,91	25	С	4,94	1,62	29	A
Apical leaf adaxial trichome density	382,60	98,36	2	A	243,40	88,79	2	в	215,60	90,21	Ś	В	316,20	60,91	Ś	AB
Apical leaf abaxial trichome density	518,20	147,30	2	Α	331,00	137,05	5	В	420,60	116,48	Ś	AB	491,60	119,88	Ś	AB
Basal leaf adaxial trichome density	ł	1	ł	ł	ł	1	ł	ł	28,40	3,21	Ś	ł	42,80	10,21	Ś	ł
Basal leaf abaxial trichome density	1	1	1	ł	1	1	1	1	116,20	36,92	Ś	1	108,40	33,91	Ś	1
Apical leaf depth of lobing	0,27	0,36	10	C	0,61	0,36	20	В	0,79	0,24	15	AB	0,90	0,62	15	Α
Basal leaf depth of lobing	ł	1	ł	ł	ł	1	ł	ł	1,48	0,38	15	ł	2,01	0,92	15	1
Apical leaf surface area	10,67	6,54	25	Α	3,49	2,54	25	В	2,54	1,17	25	В	3,02	1,93	25	В
Basal leaf surface area	ł	ł	ł	ł	ł	ł	ł	ł	9,99	4,12	25	ł	19,86	7,68	25	ł
Staminate corolla diameter	4,01	0,62	25	Α	3,46	0,31	16	В	2,24	0,45	16	D	3,02	0,44	23	C
Hermaphrodite corolla diameter	4,75	0,58	25	Α	4,03	0,35	16	В	3,00	0,37	16	D	3,58	0,50	17	C
Staminate calyx lobe length	1,13	0,14	7	Α	1	1	1	ł	0,35	0,09	15	С	0,88	0,14	10	В
Hermaphrodite calyx lobe length	2,23	ł	-1	A	ł	ł	ł	ł	0,35	0,09	9	С	1,16	0,14	14	В
Fruiting pedicel length	4,22	0,65	19	A	3,45	0,64	14	В	2,70	0,18	13	C	1,65	0,34	12	D
Fruit length	2,15	0,34	29	В	1,80	0,29	13	С	3,11	0,29	14	А	1,65	0, 13	3	С

Ē		S. wa	tneyi			S. ebui	штәи.			S. divers	iflorum			S. job	ionii	
Character	Μ	SD	u	CL	Μ	SD	u	С	Μ	SD	u	CL	Μ	SD	u	CL
Fruit width	1,96	0,36	29	BC	2,20	0,41	13	В	2,92	0,35	14	Α	1,68	0,28	3	U
Seeds per fruit	53,11	28,45	28	С	78,69	36,67	13	В	433,00	ł	1	А	101,67	58,60	3	В
Plant height	45,85	6,90	25	А	43,62	10,86	16	AB	33,80	4,44	3	BC	34,50	6,26	7	С
Seed length	3,05	0,18	20	В	2,84	0,21	20	C	4,11	0,25	15	А	3,09	0,21	15	В
Fruit wall width	5,50	ł	1		3,10	ł	1		4,40	ł	1		2,20	1	1	

Table 2. Comparison of key qualitative characters across the four closely-related taxa of the Solanum eburneum species group, including S. jobsonii.

Character	S. matnewi	S. churneum	S. diversiflarum	S. iohsonii
Plant habit	sprawling/lax, open	erect, compact	lax branches and leaves	erect or lax, compact
Lobing of leaves, # lobes	± shallow (if present), few, 0–2 per leaf	deep, numerous, 6–8 per leaf	pinnatifid, 4–8 per leaf	dissected, 6-12 per leaf
Corolla color	lighter purple, 'dusty purple'	darker purple, 'mauve'	medium purple	medium purple
Corolla margins	wavy, undulating	more or less flat	repand	involute
Fruit shape	± ellipsoidal	± globose	± globose	± globose
Fruit color at maturity	yellow, 'light lemon' with light brown striping	white, 'creamy' without striping	light yellow-green with dark green striping	yellow, creamy yellow
Fruit interior at maturity	more or less dry	liquid-filled	liquid-filled	liquid-filled
Fruit firmness at maturity	firm	soft, squishy	firm	firm
Fruit position at maturity	pendant, on or near ground	pendant from stems, but not on ground	pendant from stems, but not on ground	pendant from stems, but not on ground
Seed color	light to dark brown	black	tan to light brown	dark brown to black
Soil type	well-drained limestone based sandy- or clayey- loamy soil	gray clay soil	red sandy soil	clayey soil with laterite pebbles



**Figure 2.** *Solanum jobsonii* Martine, J.Cantley, and L.M.Lacey and related species. **A** Typical habitat in clay soils with limestone stones and laterite pebbles, Limmen National Park, NT **B** *S. jobsonii* in flower and **C** in mature fruit **D** Corolla comparisons of staminate (upper) and hermaphrodite (lower) flowers for *S. jobsonii* (left) and *S. diversiflorum* (right) **E** Leaf shape across varying leaf ages for *S. jobsonii* (top) and *S. diversiflorum* (bottom) **F** *S. jobsonii* immature fruit with armed calyx **G** Corolla comparisons of staminate (upper) and hermaphrodite (lower) flowers for *S. eburneum* (left) and *S. watneyi* (right) **H** Leaf shape across varying leaf ages for *S. watneyi* (top) and *S. eburneum* (bottom) **I** Seed size, shape, and color comparisons from left to right – *S. jobsonii*, *S. diversiflorum*, *S. eburneum*, and *S. watneyi* **J** *S. jobsonii* trichome density of apical adaxial leaf surface (top) and apical abaxial leaf surface (bottom). Photos **A, B, C, F, G** by J.T. Cantley; **H** by E.S. Frawley; **D, E, I, J** by L.M. Lacey. Yellow scale bars: **B, D, F, G** = 1.5 cm; **C** = 5 cm; **E, H** = 2.25 cm; **I** = 8 mm; **J** = 1.5 mm.

**Description.** Lax to weakly erect sub-shrub or short-lived perennial herb to 20–50 cm tall. Stems slender, woody, upright even when weighted by fruits; initially single stemmed, with strong lateral branching beginning at ca. 7 cm; internode length on mature stems ca. 1.5 cm. Overall plant aspect dark green to gray-green, becoming slightly more yellow-green with age; pubescence of stems short and loose; moderately to densely pubescent throughout with stellate stalked trichomes, the stalk 0.05–0.1 (rarely to 0.2) mm long, with 6–8 rays 0.2–0.4 mm long, the midpoint elongate, to 0.4 mm long. Prickles sparse to moderately dense, straw-colored, straight, slightly widened at base,

fine, 1-6 mm long, scattered on stems. Sympodial units difoliate, the leaves solitary or geminate. Mature leaves  $5-9 \text{ cm} \times 1.5-5 \text{ cm}$ , linear to lanceolate or elliptic, with 1-4 pairs of primary veins, with only a few prickles along midvein on leaf undersides; young leaves lighter green and gray-hairy but becoming dark green above, slightly paler beneath, both sides closely and densely stellate-pubescent, the older leaves becoming scabrous and uniformly dark on both sides, retaining dense pubescence primarily only along veins; base tapering; margins deeply incised and 6-12 lobed, occasionally shallowly lobed or nearly linear; apex blunt; petiole 0.3–2.3 cm long with few to no prickles. Inflorescence a supra-axillary andromonoecious cyme 1–6.5 cm long, consisting of a basal hermaphrodite flower and a distal group of 2-5 (usually) staminate flowers; typically 2-5 staminate flowers open at a time; common peduncle typically 1.5-2.5 mm long; rachis slightly less pubescent than stems. Flowers 5-merous, heterostylous with a single hermaphroditic flower at the base of the inflorescence and the plants andromonoecious. Hermaphrodite flower ca. 1.5-3 cm below the staminate flowers, usually opening first or soon after lowest 1–2 staminate flowers; pedicel ca. 2 cm long at anthesis, elongating further after fertilization, armed with prickles 1-4 mm long; calyx lobes ca. 11-15 mm long and fused for first 2-3 mm, some pairs occasionally fused entirely with sepals arranged 2+2+1, armed with long, straight prickles and stellate trichomes; corolla 2.5–4.5 cm in diameter, medium purple, rotate, free of indumentum; stamens equal; filaments ca. 1.5 mm long; anthers 5 mm long, oblong-lanceolate to somewhat tapered, poricidal at the tips, in a tight anther cone; ovary glabrous, ca. 2 mm diameter at anthesis; style 6–11.5 mm long (including capitate stigma), curved. Staminate flowers with pedicels 9-14 mm long, unarmed or with few prickles; calyx lobes 6-10 mm long and fused for first 1-2 mm, occasionally 2+2+1 as above, with a few 1-4 mm weak prickles or prickles absent; corolla 2.5–3.5 cm in diameter, medium purple, broadly stellate to rotate; acumens ca. 0.5 mm long; stamens of same proportions as in hermaphrodite flower; ovary, style, and stigma vestigial and not exserted beyond the stamens. Fruit a globose berry 1.6-1.8 cm long, 1.5–2.0 cm wide, light green with darker green stripes when young, maturing to creamy yellow; flesh firm; locules 2, liquid-filled; fruit wall ca. 2.2 mm thick; fruits retained on plant after maturation. Fruiting pedicels 1.2-2.3 cm long. Fruiting calyx enclosing and exceeding fruit in early development, eventually covering 1/4 to 1/3 of developed fruit, the lobes narrowly triangular, long-acuminate, blunt-tipped, turning brown and weakly reflexing as fruit matures, short stellate-pubescent and armed with sharp spines 2-5 mm long, these single or paired along the calyx sutures. Seeds up to ~135 per fruit, 2.8–3.6 mm long, dark brown to black, flat, reniform, finely reticulate.

**Distribution and ecology.** Solanum jobsonii is presently known mostly from a restricted range of localities in Limmen NP in the sub-arid, monsoon-influenced zone of northeastern Northern Territory (Fig. 3) at elevations around 250 feet. The species is locally abundant in a few sites along and just off of the Nathan River Road, yet abundance elsewhere is not known. *Solanum jobsonii* is primarily associated with *Eucalyptus pruinosa* Low Open Woodland (Cowie et al. 2011) on seasonally-flooded alluvial plain fringes (above seasonal streams) and plains. The most abundant population encountered in 2016 was in a *Eucalyptus pruinosa* Schauer subsp. *pruinosa* (Myrtaceae) woodland on



**Figure 3.** Geographic distribution of *S. watneyi*, *S. eburneum*, *S. diversiflorum*, and *S. jobsonii* in eastern Western Australia and the Northern Territory, Australia, based on specimens held at the Northern Territory Herbarium Palmerston (DNA).

grey-brown clay with limestone stones and laterite pebbles where the primary associated taxa were *Melaleuca nervosa* (Lindl.) Cheel (Myrtaceae), *Dodonaea physocarpa* F.Muell. (Sapindaceae), *Dolichodandrone heterophylla* (R.Br.) F. Muell. (Bignoniaceae), *Grewia retusifolia* Kurz (Malvaceae), *Carissa lanceolata* R.Br. (Apocynaceae), *Eulalia aurea* (Bory) Kunth (Poaceae), *Calandrinia gracilis* Benth. (Portulacaceae), herbs and grasses. Although *S. jobsonii* is nearly always found in *E. pruinosa* woodlands, the converse is not true; *S. jobsonii* was not present in many of the *E. pruinosa* stands in which we searched. This suggests that *S. jobsonii* is sensitive to fine-scale habitat variation that we did not observe.

Nothing is known about pollination biology or seed dispersal of *S. jobsonii*, but floral morphology aligns with the typical *Solanum* buzz pollination syndrome (see Anderson and Symon 1988) and the fleshy berries suggest biotic dispersal (see Symon 1979). Plants encountered in May 2016 bore numerous mature fruits that had not been taken by frugivores – a phenomenon also seemingly typical among close relatives.

Although *S. jobsonii* has been collected on the edges of graded roads and appears to be disturbance-adapted, the species only appears where these thoroughfares bisect otherwise suitable habitat where seasonal flooding is also apparent. Occasional bushfires figure prominently into the ecology of these sites, but the effect on *S. jobsonii* is unknown.

**Phenology.** The few collections made of flowering material are from the early months of the dry season, April-June, but first flowers likely bloom during the wet season (November-March) given the observation of mature fruits in April and onward. Under greenhouse conditions *S. jobsonii* fruits mature around 60 days after hand pollination. Successful *ex situ* autogamous and geitonogamous pollinations infer that the species is self-compatible.

**Etymology.** The specific epithet of "jobsonii" is selected to honor Peter Jobson, Senior Botanist at the Northern Territory Herbarium at Alice Springs, an expert on the Northern Territory flora and the leader of the 2016 expedition to collect this and numerous other *Solanum* taxa with the authors.

Preliminary conservation status. Cowie et al. (2011) noted that Limmen NP is home to nearly 1200 plant taxa, including two, Seorsus intratropicus (F.Muell.) Rye & Trudgen (Myrtaceae) and Triodia longiloba Lazarides (Poaceae), for which Limmen is considered the primary center of their distribution. Solanum jobsonii follows the pattern of these two taxa in its being restricted to specialized habitats and being largely known from this single national park, thus we suggest that it also be added to the park's list of species of conservation significance (Cowie et al. 2011). The species is known from only four populations (even after much searching by the authors in other potentially-appropriate habitats), each consisting of a few dozen individuals. When evaluated using the IUCN Red List Categories and Criteria for extinction risk (IUCN 2001), S. jobsonii falls into the Vulnerable (VU) category under Criterion B (B1ab(iii)+2ab(iii)). The VU designation is the lowest of three threatened categories, but indicates the taxon still faces a high risk of extinction in the wild. It has an Area of Occupancy < 2000 km<sup>2</sup> and Extent of Occurrence < 20,000 km<sup>2</sup>, less than 10 known locations that are possibly fragmented, and observed decline in overall habitat quality. Suitable habitat will continue to decline without active conservation management.

**Specimens examined. AUSTRALIA. Northern Territory:** Limmen National Park, just north of Lorella Springs turn off, 15°54'44"S, 135°31'42"E, 17 April 2008 (fl, fr), *D.J. Dixon 1745* (DNA); Limmen National Park, Nathan River Road, 3.7 km north of Lorella Springs turnoff, 15.94913°S, 135.53464°E, elev. 246 ft., 14 May 2016 (fl, fr), *C.T. Martine, J.T. Cantley, L.M. Lacey and P. Jobson 4226* (DNA, BUPL); Limmen National Park, jct. Lorella Springs Rd. and Nathan River Rd., 15.91605°S, 135.52926°E, 14 May 2016 (fl, fr), *C.T. Martine, J.T. Cantley, L.M. Lacey and P. Jobson 4227* (DNA, BUPL); Benmara Station, approx. 1 km west No. 38 Bore, 17°54'--"S, 136°57'--"E, 5 June 1984 (fl), *Strong 253* (DNA); Limmen National Park, along main road, 16°01'39"S, 135°33'24"E, 8 May 2010 (fl, fr), *B. Stuckey & I.D. Cowie 595* (DNA); Savanna Way between Nathan River and Borroloola, 15°47'44"S, 135°25'46"E, 15 July 2008 (fl), *H. van der Werff & B. Gray 222501* (DNA); Limmen National Park P, Nathan River Rd., Lorella Springs turnoff, 15°54'56"S, 135°31'46"E, 12 May 2010 (fl, fr), *B. Wirff 531* (DNA).

**Discussion.** Morphological comparisons of *S. jobsonii* and its close relatives, *S. wat*neyi, *S. eburneum*, and *S. diversiflorum*, demonstrate a statistically significant difference among the four taxa. Most notably, S. jobsonii differs from the other three species by its involute corolla margins, deeply dissected leaves with 6-12 lobes, smaller creamyyellow fruits, and a set of nine morphometric characters highlighted in Table 1[including corolla diameter (in both staminate and hermaphrodite flowers), calyx lobe length, and length of the fruiting pedicel]. While leaf lobing can be a rather variable character within and between Solanum species, the deeply-cut sinuses of S. jobsonii (and the occasionally linear leaf lobes/blades) are quite visually distinctive - and this character holds up in comparison to the close relatives in both field collections and in cultivation. The new species maintains a distinct geographic distribution from its closely related congeners, inhabiting limited areas on gray-brown clayey soil with limestone stones and laterite pebbles in the region of Limmen National Park in the northeastern portion of the Northern Territory. The species is named after Peter Jobson, Senior Botanist at the Northern Territory Herbarium at Alice Springs, who organized and led the expedition during which the new species was most recently collected and confirmed as distinct. Solanum jobsonii is one of the first new plant species described from Limmen NP, an area that received formal protection in only 2012.

National parks are under threat throughout the world, with federally-protected lands in places like the United States in potential danger of being left unfunded, deforested, or sold into private ownership (The Guardian 2017). By contrast, the 10,000 km<sup>2</sup> Limmen NP is a new acquisition for the Northern Territory Government and, in its short time under protection, has already proved to be a cradle of impressive biodiversity (Cowie et al. 2011). Notably, the use of trained biodiversity scientists in surveys of the proposed parkland provided masses of data in support of protecting this area as a national treasure. The discovery of the new species described here, and the potential description of other new forms of biodiversity from Limmen NP, is a testament to the benefits of not only investing in national parks in Australia and elsewhere, but also investing in parks-based scientific inquiry.

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**RESEARCH ARTICLE** 



# Eutrema giganteum (Brassicaceae), a new species from Sichuan, southwest China

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#### Abstract

*Eutrema giganteum* (Brassicaceae), a new species from Hengduan Mountains in Sichuan Province, southwest China, is described, and its relationships to the closely related *E. yunnanense* is discussed based on morphological, cytological, and molecular data. It is similar morphologically to *E. yunnanense* but is readily distinguished by having robust (vs. slender), erect (vs. decumbent), and branched (vs. mostly simple), and rather tall stems (60–110 cm vs. 20–60 cm); curved (vs. straight), smooth (vs. torulose), and shorter fruit (5–8 mm vs. 8–15 mm); and fewer ovules per ovary (1–4 vs. 6–10). All examined individuals from different populations of *E. giganteum* clustered into a single clade sister to *E. yunnanense* in phylogenetic analyses using the combined nuclear ITS and plastid DNA datasets. Our cytological studies revealed that the chromosome number of *E. giganteum* is 2n = 44, with a genome size of 1160 (±8) Mb, while that of *E. yunnanense* is 2n = 28, with a genome size of 718 (±15) Mb. Multiple lines of evidence support the recognition of *E. giganteum* as a distinct species well differentiated from *E. yunnanense*.

#### Keywords

Brassicaceae, Cruciferae, Eutrema giganteum, new species, Eutrema yunnanense, molecular phylogeny

<sup>\*</sup> These authors contributed equally to the work

#### Introduction

*Eutrema* R.Br. (Brassicaceae) is an important genus that includes the model plant for salt-tolerance *E. salsugineum* (Pall.) Al-Shehbaz & Warwick and the economic wasabi plant *E. japonicum* (Miq.) Koidz. This genus was expanded to comprise 26 species (Al-Shehbaz and Warwick 2005; Warwick et al. 2006) with 16 transferred from four previously genera, *Taphrospermum* C.A.Mey., *Thellungiella* O.E.Schulz, *Neomartinella* Pilger, and *Platycraspedum* O.E.Schulz (Al-Shehbaz and Warwick 2005; Warwick et al. 2006). Since then, several new species were described (Ning et al. 2005; Al-Shehbaz 2007; Gan and Li 2014; Xiao et al. 2015; Hao et al. 2015, 2016).

During botanical expeditions to Hengduan Mountains in southwest China from 2013 to 2016, we discovered three populations of *Eutrema* that were strikingly unusual in having large size, big cordate leaves, and stout, erect and branched stems. Only *E. yunnanense* Franch. has such similar big cordate leaves  $(10-20\times10-16 \text{ cm})$ , but its stems are slender, decumbent, and rarely branched. Therefore, it was immediately suspected these populations may represent an undescribed new species. In order to further test this hypothesis, morphological, molecular, and cytological studies are presented here on those two species and two related species *E. japonicum* and *E. thibeticum* Franch. were conducted with herein.

#### Material and methods

For morphological comparisons and taxonomical treatments, we examined more than ten living individuals from each population of *Eutrema giganteum* (three populations) and *E. yunnanense* (two populations), and photos of all herbarium specimens of *E. yunnanense* preserved in the Chinese Virtual Herbarium (http://www.cvh.org. cn/). We followed Hu et al. (2015) and Hao et al. (2015, 2016) in examining genetic differences between two morphological groups, and three individuals were studied from each population. In order to determine the systematic position of *E. giganteum*, we further sampled two populations each for *E. japonicum* and *E. thibeticum* because they were phylogenetically related to *E. yunnanense*. We sampled one individual each of *E. schulzii* Al-Shehbaz & Warwick, *E. heterophyllum* (W.W. Sm.) H. Hara, *E. verticillatum* (Jeffrey & W.W. Sm.) Al-Shehbaz & Warwick, *and E. salsugineum* as ingroups. We chose one sample of *Chalcanthus renifolius* (Boiss. & Hohen.) Boiss. as the outgroup. The distribution of sampled populations listed in Table 1. Voucher specimens were deposited in the Sichuan University Herbarium (SZ).

We extracted total DNA from silica gel-dried leaves using the modified CTAB method (Doyle and Doyle 1990). The internal transcribed spacer (ITS) and four chloroplast DNA regions (*trnL*-F, *psbA-trnH*, *rbcL*, *matK*) were amplified for phylogenetic analyses. The five pairs of primers used for amplifying and sequencing *trnL*-F, *psbA-trnH*, *rbcL*, *matK* and nuclear nrITS were the same as those used by Hu et al. (2015). PCR amplification and sequencing approaches followed Hu et al. (2015) and Hao et al. (2015). For those ITS sequences with double peaks in those possible hybrids, we further cloned them

Taxon	Voucher	Source	Coordinate	Elevation
				(m)
E. giganteum	J.Quan Liu & G.Q. Hao 15032	Xiling Snow Mountain, Sichuan	30°40'N, 103°09'E	2340
E. giganteum	J.Quan Liu & G.Q. Hao 15055	Erlang Mountain, Sichuan	29°50'N, 102°18'E	2480
E. giganteum	J.Quan Liu & G.Q. Hao 15069	Gongga Mountain, Sichuan	29°35'N, 102°01'E	2620
E. yunnanense	J.Quan Liu & G.Q. Hao 15096	Cangshan Mountain, Yunnan	25°52'N, 99°59'E	3100
E. yunnanense	J.Quan Liu & G.Q. Hao 13106	Haba Mountain, Yunnan	25°52'N, 99°59'E	3102
E. japonicum	J.Quan Liu & G.Q. Hao 13148	Erlang Mountain, Sichuan	29°51'N, 102°18'E	2300
E. japonicum	J.Quan Liu & G.Q. Hao 14001	Longchi, Dujiangyan, Sichuan	31°07'N, 103°48'E	1567
E. thibeticum	J.Quan Liu & G.Q. Hao 14003	Jinfo Moutain, Chongqing	28°59'N, 107°11'E	1591
E. thibeticum	J.Quan Liu & G.Q. Hao 15031	Xiling Snow Mountain, Sichuan	30°37'N, 103°10'E	1380
E. integrifolium	J.Quan Liu & G.Q. Hao 13049	Tian Shan, Xinjiang	43°12'N, 84°49'E	2300
E. schulzii	J.Quan Liu & G.Q. Hao 13132	Jianziwan Shan, Sichuan	30°00'N, 100°51'E	4400
E. salsugineum		Cultivated, seeds from Shandong		

Table 1. The sources of materials used for molecular analyses.

\*All vouchers were housed in the Sichuan University Herbarium (SZ).

using vector pGEM-T (Promega, Madison, Wisconsin). We selected ten positive clones for sequencing with primers "sp6" and "t7". We deposited all new sequences in GenBank under the accession numbers KY969594-KY969625. We aligned DNA sequences using Clustal X (Thompson et al. 1997) and MEGA 5.10 (Tamura et al. 2011) and refined them manually. We concatenated sequences from all four cpDNA fragments into a single matrix for Maximum parsimony (MP) and Maximum likelihood (ML) analyses because of their common inheritance without obvious recombination. To evaluate the congruence of the plastid and nuclear datasets, we employed the incongruence length difference (ILD) test (Farris et al. 1995). The ILD test was carried out using the PAUP\* 4.10b (Swofford 2003) with the following settings: 1000 replications, each using a heuristic search with 100 random-addition-sequence replicates and TBR branch swapping. We performed ILD tests between each pair of the cpDNA dataset, and between the nrITS dataset and the combined cpDNA dataset. The P-values smaller than 0.01 were considered to be significant incongruent (Cunningham 1997). We reconstructed phylogenetic relationships based on three datasets (nrITS, cpDNAs and combined nrITS+cpDNAs) respectively using MP analyses by PAUP\* 4.10b (Swofford 2003), employing a heuristic search with 10,000 replicates and TBR branch swapping. We estimated bootstrap values (Felsenstein 1985) with 1000 replicates and 100 random-addition-sequence replicates per bootstrap replicate. Because indels may contain potential phylogenetic information (Simmons et al. 2001), we coded them using the simple code method by GapCoder (Young and Healy 2003) for phylogenetic analyses. We performed ML analyses using RAxML 7.2.6 (Stamatakis 2006) with the order: raxmlHPC -f a -s sequence. phy -n boot2 -m GTRGAMMA -x 1234 -# 1000 -n outname. We selected the GTRGAMMA model and estimated ML bootstrap analyses with 1000 replicates. We followed Hao et al. (2015) to carry out chromosome number count and genome-size determination.

#### Results

#### Morphological comparison and geographical distribution

Our study of herbarium specimens and living plants demonstrated that *Eutrema gi-ganteum* is a morphologically distinctive species. As shown in Fig. 1, it is a glabrous herbaceous perennial, the tallest in the genus, with robust, erect or ascending stems 60-110(-140) cm and alternate branches. Each branch is divaricate-ascending or almost perpendicular to stem and originates from the axil of cauline leaf. The fruits are narrowly oblong,  $5-8 \times 2-3$  mm and curved, but not torulose.

*Eutrema giganteum* is most similar to *E. yunnanense*, but it is readily distinguished from the latter by having stout (vs. slender), erect (vs. decumbent), and branched (vs. rarely branched) stems (60–110 cm vs. 20–60 cm; curved (vs. straight), smooth (vs. torulose), and shorter (5–8 mm vs. 8–15 mm) fruit, and fewer ovules per ovary (1–4 vs. 6–10). Young plants of *E. giganteum* are also somewhat similar to *E. japonicum*. However, they differ in having cordate to reniform (vs. ovate to ovate-cordate) leaf blade. The cultivated plants of *E. japonicum* have stems and fruits similar to those of *E. yunnanense*. The leaves of *E. thibeticum* are similar to those of *E. yunnanense* and *E. giganteum*. However, *E. thibeticum* is comparatively weak and small (20–30 cm tall with basal leaves 2–4 cm).

According to specimen records and field investigation, *Eutrema giganteum* is currently known only from Hengduan Mountains in western Sichuan at elevation between 2300 and 2900 m (Fig. 2), while *E. yunnanense* may occurs in the southern part of Hengduan Mountain, Yunnan province, at elevation between 2500 and 3200 m. Zhou et al. (2001) reported that *E. yunnanense* is widely distributed in other provinces of China (for example, Anhui, Gansu, Hebei, Hubei, Hunan, Jiangsu and Zhejiang) at elevation between 400 and 3500 m. Phylogenetic and taxonomic relationships between populations of these provinces and those from Yunnan await future studies.

## Genetic relationship of Eutrema giganteum with E. yunnanense, E. japonicum and E. thibeticum

Based on sequence variations of nrITS, cpDNAs, and the combined nrITS and cpDNAs (Table 2), phylogenetic analyses suggested that *E. giganteum* is mostly related to *E. yunnanense* (Figs 3, 4). In the MP analyses of nrITS sequence data, *E. giganteum*, one clone of *E. yunnanense*, *E. japonicum*, and *E. thibeticum* formed a single cluster, which together was sister to the other *E. yunnanense* sequences with medium support (50%–70%). In the MP analyses of the sequence variations from cpDNAs, *E. giganteum* and *E. yunnanense* formed a single cluster, then sister to *E. japonicum* and *E. thibeticum* with higher support (>70%). The *P*-values resulting from the ILD tests show that there is significant incongruence between the four cpDNA and nrITS when including all species (P = 0.003). After removing conflicting sequences of *E. yunnanense*, *E. altaicum* 



Figure I. *Eutrema giganteum* G.Q. Hao, Al-Shehbaz & J. Quan Liu. sp. nov. **A–B** Habit **C** Leaves **D** Inflorescence **E** Flowers **F** Fruit.

and *E. verticillatum*, the *P* value rose to 1.000, indicating that there is no significant incongruence between nrDNA and cpDNA datasets. We therefore combined them for further analyses. In the MP analyses of the combined dataset, all *E. giganteum* individuals formed a single cluster, sister to the cluster comprising *E. yunnanense* individuals with medium supports (50%–90%). The clade comprising both of them was sister to the clade formed by both *E. japonicum* and *E. thibeticum* with a high support (94%) (Fig. 3). ML analyses produced similar tree topologies to MP trees but the supports were higher than MP analyses (Fig. 4).

#### Chromosome number and genome size

Two populations of *Eutrema giganteum* from Xiling Snow Mountain and Erlang Mountain, and one population of *E. yunnanense* from the type locality, Cangshan Mountain, were cytologically examined. Mitotic chromosome number of *E. giganteum* 



**Figure 2.** Geographical distribution of *Eutrema giganteum* (P1–P4) and *Eutrema yunnanense* (P5, P6). P1 = Population from Xiling Snow Mountain, Sichuan; P2 = Specimens record from Baoxing County, Sichuan; P3 = Population from Erlang Mountain, Sihuan; P4 = Population from Gongga Mountain, Sichuan; P5 = Population from Haba Mountain, Yunnan; P6 = Population from Cangshan Mountain, Yunnan,

was determined as 2n = 44 (Fig. 5), while that of *E. yunnanense* was 2n = 28, as the same as counted by Du and Gu (2004). Genome size of *E. giganteum* was determined as 1160 (±8) Mb while that of *E. yunnanense* was 718 (±15) Mb.

#### Discussion

Different species concepts emphasize the different criteria to define a new species (Wheeler and Meier 2000). An integrative practice using multiple criteria to circumscribe species boundaries and define a new species will produce relatively objective and operational taxonomy (Su et al. 2015; Hu et al. 2015; Liu 2016). Based on morphological, cytological, and molecular data, the new species *E. giganteum* is described here as a new species distinct from the closely related *E. yunnanense*. First, our observations of herbarium specimens and living plants suggested that *E. giganteum* is most similar to *E. yunnanense*, but could be distinguished by distinct morphological traits, including stem, fruit, ovule number, and individual size. Second, a species should be delimited as an evolutionarily distinct lineage (de Queiroz 1998, 2007; Stockman and Bond 2007; Fujita et al. 2012; Hendrixson et al. 2013; Mckay et al. 2013). Our molecular phylogenetic analyses of combined nrITS and cpDNA datasets, all examined individuals of *E. giganteum* clustered into a single lineage, sister to *Eutrema yunnanense*. Third, chromosome number count and genome-size measure revealed the obviously cytological discrepancy between *E. giganteum* and *E. yunnanense*. The chromosome number of

Data set	ITS*	psbA-trnH	trnL-F	rbcL	matK	Combined cpDNA <sup>*</sup>	Combined cpDNA and ITS*
No. of sequences	37**	34	34	34	34	34	32**
Aligned length used in analyses	606	332	665	482	728	2288	2894
No. of variable characters	97	64	54	7	61	238	280
No. of parsimony- informative char- acters	34	20	26	4	23	93	96
Tree length (steps)	138	78	59	7	68	291	330
Consistency (CI)	0.804348	0.910256	0.983051	1	0.911765	0.859107	0.900000
Retention index (RI)	0.795455	0.907895	0.986301	1	0.934783	0.880117	0.909341
Rescaled consistency index (RC)	0.639822	0.826417	0.969584	1	0.852302	0.756114	0.818407

**Table 2.** Tree statistics for analyses of the seven data sets.

\*gaps were coded and included;

\*\*the cloned sequences were included

*E. giganteum* is 2n = 44, whereas *E. yunnanense* has the number of 2n = 28. Consistent with the difference of the chromosome number, we also found that the genome size of *E. giganteum* is almost 1.5 times larger than that of *E. yunnanense*. These chromosomal and genomic differences are likely to lead to the obvious reproductive isolations between *E. giganteum* and *E. yunnanense*. In addition, our unpublished data suggested that some populations of *E. thibeticum* have the chromosome number of 2n = 16. Both *E. giganteum* and *E. thibeticum* are co-distributed in the Hengduan Mountains in western Sichuan where the former occurs at the high elevation while the latter at the low elevation. It seems likely that *E. giganteum* (2n = 44) originated from a hybridization between *E. thibeticum* (2n = 16) and *E. yunnanense* (2n = 28) although further molecular evidence and experimental hybridization are needed. Overall, all available lines of evidence suggest that *E. giganteum* should be recognized as a distinct new species.

#### **Taxonomic treatment**

Eutrema giganteum G.Q. Hao, Al-Shehbaz & J. Quan Liu, sp. nov.

urn:lsid:ipni.org:names:77163811-1 巨型山嵛菜

Type. China. Sichuan: Dayi County, Xiling Snow Mountain, Heishuihe Giant PandaNature Reserve, 30°40'22"N, 103°9'47"E, 2340 m, 6 July 2015, J. Quan Liu & G. Q.Hao 2015032-1 (Holotype, SZ)., J. Quan Liu & G. Q. Hao 2015032-2 (Isotype, SZ),J. Quan Liu & G. Q. Hao 2015032-3 (Isotype, SZ). Figure 1.

**Etymology.** The specific epithet refers to the remarkably huge plant size. The erect stem can extend to around 60–110 (–140) cm, higher than all the other *Eutrema* species.



**Figure 3.** The strict consensus tree constructed based on nrITS data (**A**), four cpDNA regions (**B**) and the combined nrITS and cpDNAs dataset (**C**). Bootstrap support values are given above branches receiving > 50% bootstrap support **A** The 100% strict consensus tree of 667 most maximum parsimony trees based on the analysis of nrITS data **B** The 100% strict consensus tree of 8 trees based on the analysis of 4 cpDNA regions **C** The 100% strict consensus tree of 225 trees based on analysis of combined nrITS and 4 cpDNA regions.

**Description.** Herbs, perennial, glabrous or sparsely pilose on upper parts; rhizome fleshy, to 2 cm in diam. Stems 60-110(-140) cm tall, robust, to ca. 1 cm diam, erect or ascending, simple at base, alternately branched above; branches 1-leaved, divaricate-ascending or almost perpendicular to stem. Basal leaves rosulate; petiole with a groove, hollow, cylindrical, (12-)15-26 (-35) cm; leaf blade cordate,  $(18-)25-35(-40) \times (15-)20-30(-35)$  cm, margin dentate, denticulate or repand, with distinct apiculate



**Figure 4.** The Maximum likelihood tree based on analysis of the combined nrITS and four cpDNA dataset regions dataset. Bootstrap support values are given above branches receiving > 50% bootstrap support.



**Figure 5.** Photomicrographs of mitotic chromosomes of *Eutrema giganteum*. **A** population from Xiling Snow Mountain **B** population from Erlang Mountain.

callosities terminating ultimate veins, apex subacute to acuminate; cauline leaves with petioles gradually shorter upward, cordate to lanceolate, lowermost cauline  $6-10 \times 3-7$  cm, gradually reduced in size upward. Racemes ebracteate, lax, elongated in fruit, main branch 20–30 cm; fruiting pedicels slender, reflexed or spreading, 0.6–1.5(–

2.2) cm. Sepals ovate or oblong,  $1.5-2 \times ca$ . 1 mm, deciduous; petals white, oblong-spatulate,  $3.5-5(-7) \times 1.5-2$  mm, apex obtuse to rounded; claw present; filaments white, 3-4.5 mm; ovules 1-4 per ovary. Fruit dehiscent silicles, narrowly oblong,  $5-8 \times 2-3$  mm, curved, not torulose; valves with an obscure midvein; gynophore absent or obsolete, septum complete. Seeds oblong,  $2.5-3.5 \times 1.5-2.0$  mm.

Phenology. Flowering: April–July; fruiting: May–August.

**Distribution and habitat.** *Eutrema giganteum* is currently known from Hengduan Mountains in western Sichuan, China, including Xiling Snow Mountain, Jiajin Mountain, Erlang Mountain, and Gongga Mountain (Fig. 2). It grows in shady, humid forests at elevation of 2200–2900 m.

Additional specimens examined (paratype). China: Sichuan: Baoxing County, 1954, Z. P. Song 38379 (KUN); Baoxing County, Puxi Gou, April 1959, 2700 m, Sichuan Economic Plant Investigation Team 00324 (CDBI); Luding County, Dawanzi, 2300 m, 2 May 1980, Q. Q. Wang 22061 (CDBI); Dayi County, Heishuihe Nature Reserve, 2900 m, 6 June 2007, D. H. Zhu, Z. B. Feng, C. Zhang & F. Wang 20070659 (PE).

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**RESEARCH ARTICLE** 



## Coelogyne putaoensis (Orchidaceae), a new species from Myanmar

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#### Abstract

*Coelogyne putaoensis*, a new species of section *Ocellatae* from Putao, Kachin State, Myanmar, is described and illustrated. It is morphologically similar to *C. taronensis* and *C. weixiensis*, presumably its nearest relatives. An identification key and colour photographs are provided. A preliminary risk-of-extinction assessment according to the IUCN Red List categories and criteria is given for the new species.

#### **Keywords**

Arethuseae, Kachin, key, montane forest, section Ocellatae, taxonomy

#### Introduction

*Coelogyne* Lindl. (Lindley 1821) (Orchidaceae, Epidendroideae, Arethuseae) is a genus of about 200 species, distributed from South and Southeast Asia into the Pacific as far east as Fiji and Samoa (Clayton 2002, Chen et al. 2009, George and George 2011, Gravendeel 2005). Around 45 species of *Coelogyne* have been recorded from Myanmar (Kress et al. 2003; Kurzweil and Lwin 2014). During fieldwork in Putao, Kachin State, Northern Myanmar, in June 2016, the first authors discovered a new species of *Coelogyne*, which is described below. The new species belongs to *Coelogyne* section *Ocellatae* Pfitzer & Kraenzl. (Pfitzer and Kraenzl. 1907).

#### Material and methods

All measurements of the three species here discussed, i.e., *Coelogyne putaoensis*, *C. taronensis* Handel-Mazzetti and *C. weixiensis* X.H. Jin, were taken from dried herbarium specimens and field notes. In the description, length and width are represented as length  $\times$  width. About twenty living plants and three dried specimens of the new species and 10 specimens each of *C. taronensis* and *C. weixiensis*, including types or photos of types of all taxa, were examined.

#### **Taxonomic treatment**

*Coelogyne putaoensis* X.H. Jin, L.A. Ye & Schuit., sp. nov. urn:lsid:ipni.org:names:77163812-1 Figures 1–3

**Diagnosis.** *Coelogyne putaoensis* is similar to *C. taronensis* and *C. weixiensis*, but can be distinguished by its solid yellowish brown sepals and petals, a brown lip with bright yellow markings, three keels extending from the base of the lip onto the mid-lobe, and lateral keels adorned with papillae.

**Type.** MYANMAR. Kachin State: Putao Township, Hponkanrazi Wildlife Sanctuary, subtropical, evergreen, broad-leaved, montane forest, 2500–3100 m, epiphytic on tree trunks or lithophytic on rocks, 14 June 2016, *Xiaohua Jin et al, PT-2116* (Holotype, PE!).

**Description.** Pseudobulbs crowded on a short and stout rhizome, ovoid, 2.5–3.2  $\times$  0.8–0.9 cm, when mature covered with brown sheaths at the base, bifoliate. Leaves erect, petiolate, ovate-lanceolate,  $6.5-9.5 \times 1.2-1.8$  cm, including the ca. 1 cm long petiole, acute to acuminate, coriaceous, with 5-7 veins. Inflorescence proteranthous, peduncle arching, 2–3.5 cm long, rachis slender, 2.5 cm long, 2- to 3- flowered. Flowers yellowish brown, up to 6 cm across, lip adaxially on the mid-lobe with a large, bright yellow patch, connected to a bright yellow blotch on the front part of each of the side lobes, the keels orange-brown with much paler, almost whitish marginal papillae. Pedicel-with-ovary 2.2–2.5 cm long, glabrous. Dorsal sepal narrowly elliptic,  $3.2 \times 1.3$  cm, 7-veined, acute. Lateral sepals oblique, oblong-lanceolate,  $3.5 \times 1$  cm, 7-veined, acuminate. Petals narrowly oblanceolate, 2.9 × 0.5 cm, 5-veined, acute at apex, clawed at base. Lip 3-lobed, 2.7 × 1.6 cm; lateral lobes rounded, erect; mid-lobe triangular,  $1.6 \times 1$  cm, margin undulate and lacerate; callus of three keels, extending from the base of lip to the middle (lateral keels) or apex of the mid-lobe (central keel), the central one lower than the lateral two on the mid-lobe, margins of the lateral keels adorned with papillae. Column arching, winged at apex, 1.9 cm long. Fruit not seen.

**Etymology.** The new species is named after Putao, the northernmost town of Myanmar near which it was discovered in a vast area of unspoiled mountain forest.



**Figure 1.** *Coelogyne putaoensis* X.H. Jin, L.A. Ye & Schuit. **A** Inflorescence **B** Dorsal sepal **C** Lateral sepals **D** Petal **E** Lip **F** Lateral view of column. Illustration by Yunxi Zhu.

**Distribution and habitat.** *Coelogyne putaoensis* is a predominantly epiphytic species that grows on moss-covered branches and tree trunks, sometimes also on rocks, in humid, broad-leaved, evergreen, montane forest, from 2500 to 3100 m elevation. At present, *C. putaoensis* is only known from the type locality.



Figure 2. Habit of *Coelogyne putaoensis*. Photo by X.H. Jin.



**Figure 3.** Close-up of flower of *Coelogyne putaoensis*, showing the white papillae on the two lateral lamellae. Photo by X.H. Jin.

**Conservation status. Least Concern (LC).** *Coelogyne putaoensis* was collected in the Hponkanrazi Wildlife Sanctuary, Putao, Northern Myanmar. Until now, only one population, consisting of ca. 200 individuals, has been discovered in the reserve (1044 square miles), which is a legally protected area under the management of the Myanmar Forest Department. As no threat currently affects the quality of its habitat and the number of mature individuals, the species is here assigned a preliminary status of Least Concern (LC) according to the guidelines for using the IUCN Red List Categories and Criteria (IUCN Standards and Petitions Subcommittee 2017).



Figure 4. Close-up of flower of *Coelogyne weixiensis*. Photo by X.H. Jin.



Figure 5. Close-up of flower of *Coelogyne taronensis*. Photo by X.H. Jin.

#### Key to Coelogyne putaoensis, C. taronensis and C. weixiensis

1 Flowers almost solid yellowish brown, except for yellow patches on the lip; lip with three lamellate keels, all extending onto the mid-lobe, the lateral ones Flowers white, light greenish or light yellow, sepals and petals with or without darker veins, lip with two or four orange to red-brown blotches (resembling eye-spots) and with two or three lamellate keels, the central one, if present, not extending onto the mid-lobe; the lateral ones without marginal papillae...... 2 2 Sepals and petals white or greenish white, without coloured veins; dorsal sepal 11-veined; lip usually with 4 eye-like yellow blotches bordered with brown, two on the mid-lobe and two on the side-lobes; mid-vein white ..... Sepals and petals yellowish with orange-brown veins; dorsal sepal 7-9-veined; lip with two solid brown spots on the side-lobes, sometimes with an orange patch between the keels on the mid-lobe; mid-vein brown ...... Coelogyne weixiensis

#### Discussion

Coelogyne taronensis, C. weixiensis and C. putaoensis are similar, both in vegetative morphology and in the size and shape of the flowers, and all come from the same general region, northern Myanmar and adjacent parts of China. There can be little doubt that they are closely related. They are readily distinguished on the basis of their colour differences, as indicated in the key and photos. *Coelogyne weixiensis* (Figure 4) and C. taronensis (Figure 5) are especially similar morphologically. They are listed as synonyms by George and George (2011). At present, too little is known about the variability of C. taronensis to make any assessment with confidence. Both taxa appear to be rare and local (C. weixiensis: China, Yunnan, Bilou Snow Mountains near Weixi; C. taronensis: China, Yunnan, Taron (=Dulong) Valley). Coelogyne putaoensis differs from the two others not only in having almost solid brown flowers, but also in the papillose margins of the keels on the lip, and in the median keel extending onto the mid-lobe. Altitudinal range and habitat are comparable for the three species: C. putaoensis was collected at 2500-3100 m, C. taronensis at 2400-3500 m, and C. weixiensis at 2600–3000 m elevation (Jin 2005). All three occur as epiphytes in montane forest. At least two of the three species (C. taronensis and C. weixiensis) are of high conservation interest, and habitat protection seems urgently needed for these. As far as we can ascertain, only C. weixiensis is currently in cultivation, having recently received a Botanical Certificate of the Royal Horticultural Society in the UK (as C. taronensis).

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**RESEARCH ARTICLE** 



## Two peculiar new species of Heteranthera Ruiz & Pavón (Pontederiaceae) from Brazil, with notes on inflorescence architecture in the family

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#### Abstract

Two new and peculiar species of *Heteranthera* are herein described. *Heteranthera catharinensis* is unique in the genus due to its glomerulate, many-flowered inflorescences, in which the flowers are restricted to the base and apex of the cincinni. It also possesses the biggest flowers in the *H. reniformis* Ruiz & Pavón species complex, with glabrous perianth lobes, medial filament, and style. On the other hand, *Heteranthera pumila* is described as the smallest known species of Pontederiaceae, with its dwarf stature, petiolate leaves with especially diminute blades, inflorescences 1–2–(3)-flowered, peduncle densely covered with glandular hairs, basal bract with glandular hairs at base, and smooth seeds, rarely possessing 7–9 inconspicuous longitudinal wings. We present detailed descriptions, illustrations, comments, a distribution map, conservation assessments for the new species, and an identification key to the Brazilian species of *Heteranthera s.l.* Finally, we discuss inflorescence morphology and terminology in Pontederiaceae, characterizing it as thyrsoid.

#### Keywords

Atlantic Forest, aquatic flora, Commelinales, mudplantains, Neotropical flora, pickerelweed

#### Introduction

*Heteranthera* Ruiz & Pavón, *nom. cons.* is currently the largest genus of Pontederiaceae, comprising 12 neotropical species, and two paleotropical species restricted to continental Africa and Madagascar [i.e. *H. callifolia* Rchb. *ex* Kunth, and *H. lutea* (H.Perrier) M.Pell.] (Horn 1985; Pellegrini 2017). In Brazil, *Heteranthera* is currently represented by nine species (i.e. 75% of the diversity of the genus), widely distributed throughout permanent and temporary freshwater bodies in the country (BFG 2015). The genus is especially diverse in the Atlantic Forest domain, where seven species are known to occur (BFG 2015).

Heteranthera was described based on Peruvian collections of H. reniformis Ruiz & Pavón, being originally characterized by its three dimorphic stamens, six-lobed perianth, and polyspermic capsules (Ruiz López and Pavón 1794). Since then, several different genera have been segregated or described to accommodate species which were considered aberrant from Heteranthera s.s. (i.e. Eurystemon Alexander, Hydrothrix Hook.f., Schollera Schreb., nom. illeg., Scholleropsis H.Perrier, and Zosterella Small). These genera were described mainly based on autapomorphic characters, such as vegetative differences (e.g. number of projections in the ligule, misinterpreted as verticillate leaves) and minor reproductive characters (e.g. number of flowers per inflorescence, number of fertile stamens, filament inflation, and anther curvature at post-anthesis; Pellegrini 2017). Several phylogenetic studies evidenced the paraphyly of Heteranthera (Eckenwalder and Barrett 1986; Graham and Barrett 1995; Kohn et al. 1996; Barrett and Graham 1997; Graham et al. 1998; Ness et al. 2011), and pointed towards a broader sense of the genus, which was subsequently accepted in taxonomic and floristic treatments worldwide (Horn 1987a, 1987b, 2002; Horn and Haynes 2001; BFG 2015; Pellegrini 2017). The genus is currently easily recognized by its non-pulvinate petiolate leaves, inflorescence reduced to a solitary cincinnus, stamens (1–)3, staminodes sometimes present, the lack of septal nectaries, and its unevenly trilobate stigma (Pellegrini 2017; Pellegrini and Horn, unpublished data).

Despite *Heteranthera* being currently monophyletic and well circumscribed (Pellegrini 2017), some widely distributed taxa are still problematic. The main neotropical species complex is represented by *H. reniformis s.l.*, which also includes the *H. multiflora s.l.* subcomplex. *Heteranthera reniformis s.l.* is the most widespread and morphologically variable taxon in the genus (Horn 1985). It is also known to be an aggressive weed, especially in rice fields around the world (Ferrero 1996; Vescovi et al. 1996; SWSS 1998; Karov et al. 2005; Domingos et al. 2005; Arakaki 2013; Csurhes 2016). Nonetheless, species identification is extremely difficult due to the poorly understood specific limits in this group. As part of our ongoing systematic studies in Pontederiaceae, based on extensive field and herbaria studies, we describe two peculiar new species segregated from *H. reniformis*, and clarify the complex's composition and morphological characterization.
## Methods

The description and phenology of the species is based on herbaria, spirit, and fresh material, and is complemented by literature information. Specimens from the following herbaria were also analyzed: AAU, ALCB, B, BA, BAF, BHCB, BHZB, BM, BOL, BOTU, BR, C, CAS, CEPEC, CESJ, COL, CORD, CTES, CVRD, E, ESA, F, FCAB, FLOR, FUEL, FURB, G, GH, GUA, HAMAB, HAS, HB, HBR, HERBAM, HRB, HRCB, HSTM, HUEFS, HUFSJ, HURB, IAC, ICN, INPA, IPA, K, KANU, LIL, LP, MA, MBM, MBML, MG, MO, MVM, MY, NBYC, NY, PMSP, PRC, R, RB, RFA, RFFP, S, SJRP, SP, SPF, UEC, UNA, UPCB, and US (herbaria acronyms according to Thiers, continuously updated). The distribution of the species is based on herbaria materials, field data, and literature. The classification of the vegetation patterns follows IBGE (2012). The indumenta and shapes terminology follows Radford et al. (1974); the inflorescence terminology and morphology follows Weberling (1965, 1989) and Panigo et al. (2011); the fruit terminology follows Spjut (1994); and general terminology follows Horn (1985). The conservation status is proposed following the recommendations of IUCN Red List Categories and Criteria, Version 3.1 (IUCN 2001). GeoCAT (Bachman et al. 2011) was used for calculating the Extent of Occurrence (EOO) and the Area of Occurrence (AOO).

## Results

We update the number of species of *Heteranthera* in Brazil from nine to 11, including the number of species endemic to the country from one to three, and the total number of species in the genus from 14 to 16. Both new species belong to the *H. reniformiss* species complex, being differentiated from *H. reniformis s.s.* based on several reproductive features (Table 1). We provide detailed morphological descriptions, comments, illustrations, and a distribution map for the new species, along with an identification key for the species of *Heteranthera* in Brazil. A morphological characterization and general comments are also provided for the *H. reniformis* species complex, with special attention to *H. multiflora* (Griseb.) C.N.Horn.

#### Taxonomy

**1.** *Heteranthera catharinensis* **C.N.Horn & M.Pell., sp. nov.** urn:lsid:ipni.org:names:77163813-1 Figs 1–3

**Diagnosis.** Similar to *Heteranthera reniformis* Ruiz & Pavón due to is petiolate leaves with reniform to broadly cordate blades, glandular-pubescent cincinnus axis, perianth lobes with a 5+1 arrangement, and straight filaments. It is unique due to its 3.2–5.5 cm

**Table 1.** Morphological characters differentiating the South American species of *Heteranthera reniformis* species complex. States in bold represent unique or distinguishing characteristics for that species. 'Populations of *H. multiflora* in Argentina and Paraguay have a much more elongate cincinnus with only a few flowers within the basal bract (spathe). "In North America, *H. multiflora* has smaller perianth tube lengths.

Characters	H. catharinensis	H. multiflora	H. pumila	H. reniformis
Leaf blade width	(14–)30–46 mm	29–65 mm	3.2–12.1 mm	13–40 mm
Peduncle	<b>3.2–5.5 cm long</b> , glabrous	0.1–1.2 cm long, glabrous	0.5–3.4 cm long, <b>glandular-</b> <b>pubescent</b>	0.5–2.2(–3) cm long, glabrous
Basal bract (spathe)	Spatulate-mucronate	Mucronate	Aristate	Mucronate
Flower arrangement	Glomerulate (condensed at the base and apex of the cincinnus)	Evenly distributed along the cincinnus	Evenly distributed along the cincinnus	Evenly distributed along the cincinnus
Cincinnus	6–17-flowered, main axis glandular- pubescent	3–13 flowered, <b>main</b> <b>axis glabrous</b>	<b>1–2(–3)-flowered</b> , main axis glandular- pubescent	3–8-flowered, main axis glandular- pubescent
Flowers exerted from the basal bract (spathe)	5–15	0-3(-10)*	0(-1)	0–3
Perianth tube length	5–7.5 mm	(3–)6–10 mm **	4.9–7.3 mm	2.5–5 mm
Perianth lobes pubescence	Glabrous	Glandular-pubescent	Glandular- pubescent	Glandular-pubescent
Central superior perianth lobe length	6.6–9.2 mm	3–7.5 mm	3.6–4 mm	2.3–5 mm
Lateral stamens	Filaments barbate with hairs of unknown color, anthers 1.0–1.8 mm long	Filaments barbate with purple hairs, anthers 0.5–1.1 mm long	Filaments barbate with lilac to pink hairs, anthers 0.4–0.6 mm long	Filaments barbate with white hairs, anthers 0.2–0.6 mm long
Central stamen	Filament glabrous, anther 1.7–2.4 mm long	Filament barbate with purple hairs, anther 1–1.9 mm long	Filament villose with white hairs, anther 1.2–1.6 mm long	Filament villose with white hairs, anther 0.6–1.4 mm long
Seeds	Unknown	Testa with 9–12 conspicuous longitudinal wings	Testa smooth or with 7–9 inconspicuous longitudinal wings	Testa with 8–14 conspicuous longitudinal wings

long, glabrous peduncles, basal bract with spatulate-mucronate apex, 6–17-flowered, glomerulate cincinnus; externally glabrous perianth lobes, central superior perianth lobe 6.6–9.2 mm long, central stamen with glabrous filament, lateral anthers 1–1.8 mm long, central anther 1.7–2.4 mm long, and glabrous style.

**Type. BRAZIL. Santa Catarina:** Ipumirim, 4–7 km south of the Rio Irani, 26°59'S, 52°11'W, alt. 500–600 m, 9 Dec 1964, L.B. Smith & R.M. Klein 13919 (holotype: US barcode US01936706!; isotypes: FLOR barcode FLOR3365!, LP!, MO!, NY!, R!).



**Figure 1.** Holotype of *Heteranthera catharinensis* C.N.Horn & M.Pell. Image courtesy of the Smithsonian Institution, NMNH, US herbarium.

Description. Herbs annual or short-lived perennials. Roots thin, delicate, unbranched, white. Stems repent on the substrate or floating in shallow water, delicate, spongy, rooting at the nodes; internodes 1.6-4.3 cm long, glabrous. Sessile leaves not seen. Petiolate leaves distichously-alternate, distributed along the stem, floating to emergent; sheaths 2.6-5.5 cm long, glabrous, covered with mucilage, longitudinally split and green when mature, ligule 2-parted, barely surpassing the sheath, 0.1–0.3 mm long, membranous, light green, glabrous, apex triangular; petiole 3.3–21 cm long, not inflated, glabrous; blades  $1.3-3.3 \times (1.4-)3-4.6$  cm, reniform to broadly cordate, membranous, glabrous, base cordate, margins glabrous, apex obtuse to slightly acute. Inflorescences axillary or apparently terminal, reduced to a solitary pedunculate cincinnus; peduncle 3.2–5.5 cm long, glabrous; basal bract (spathe)  $1.6-3.3 \times 0.3-0.5$  cm, spathaceous, elliptic, conduplicate, glabrous, green, margins hyaline, apex spatulate-mucronate; cincinnus bract absent; cincinnus 6-17-flowered, flowers congested at the base and apex of the cincinnus, 1-2 flowers included in the basal bract, axis 3–6.5 cm long, slightly to densely glandular-pubescent. Flowers bisexual, tubular, chasmogamous, sessile, enantiostylous; floral buds narrowly ellipsoid, light green, glabrous; perianth tube 5–7.5 mm long, light green, glandular-pubescent, lobes 5 superior and 1 inferior, white, lateral superior lobes  $6.6-8.3 \times 1.2-2.5$  mm, elliptic, base cuneate, apex acute to acuminate, central superior lobe 6.6–9.2 × 1.6–2.5 mm, ovate to broadly ovate, base obtuse, slightly involute, apex acute, with a nectar guide at base, pale to medium vellowish green with an upper mauve to vinaceous spot, inferior lobe  $6.5-9.5 \times 0.4-1$  mm, linear elliptic, base cuneate, apex acuminate; stamens 3, lateral stamens with filaments straight, 1.5-2 mm long, not inflated, apically barbate with eglandular, multi-celled hairs, anthers  $1-1.8 \times 0.3-0.4$  mm, oblongoid to ellipsoid, yellow, central stamen with filament straight, 3–3.6 mm long, not inflated, glabrous, anthers  $1.7-2.4 \times 0.4-$ 0.6 mm, ovate to slightly sagittate, white; ovary  $3.2-3.8 \times 1.1-1.3$  mm, linear ovoid to linear oblongoid, glabrous, 1-locular, placentation intrusive-parietal, style gently sigmoid, 5.1–9.3 mm long, glabrous, stigma unevenly trilobate, densely glandularpubescent. Capsules not seen; persistent perianth base (anthocarp) smooth, medium brown. Seeds not seen.

Specimens seen (paratypes). BRAZIL. Santa Catarina: Caçador, slough, 33 km W of Caçador, fl., 23 Dec 1956, L.B. Smith & R. Reitz 9103 (HBR!, NY!, P barcode P02188433!, US barcode US01936705!)

**Etymology.** The epithet makes reference to the type locality, the state of Santa Catarina, Brazil.

**Distribution, habitat and ecology.** *Heteranthera catharinensis* is currently endemic to the state of Santa Catarina, in the Atlantic Forest domain (Fig. 3). Is was found growing on open marshy areas and slow water environments within the Uruguay River watershed.

**Phenology.** *Heteranthera catharinensis* can be found in bloom in December. Unfortunately, neither of the two currently known collections present mature fruits, thus fruiting time remains unknown.



**Figure 2.** Line drawing of *Heteranthera catharinensis* C.N.Horn & M.Pell. **A** Detail of the leaf blade **B** Detail of the apex of the stem, showing the ligule and an inflorescence at anthesis **C** Detail of the basal bract, showing the spatulate-mucronate apex **D** Glandular hair from the cincinnus axis and floral tube **E** Dissected perianth lobes, showing the 5+1 arrangement **F** Lateral stamen **G** Uniseriate hair from the lateral stamen **H** Central stamen **I** Gynoecium, showing the glabrous style and unevenly trilobate stigma. Illustration by M.O.O. Pellegrini, based on the paratype (Smith & Reitz 9103, US).



Figure 3. Distribution map. ■ *Heteranthera catharinensis* C.N.Horn & M.Pell. ● *H. pumila* M.Pell. & C.N.Horn. Green– Paraná watershed; Yellow– Uruguay watershed; Red– Southeastern Atlantic watershed; following ANA – Agência Nacional de Águas (2002).

**Conservation status.** Following the IUCN recommendations (IUCN 2001), *H. catharinensis* should be considered as Data Deficient (DD), since it is known from only two collections, which are more than 50 years old.

**Morphological notes.** The inflorescence of *H. catharinensis* is extremely peculiar, meriting explanation. The glomerulate appearance of the inflorescence (i.e. flowers congested at the base and apex of the inflorescence) seems to be due to changes in the length of the cincinnus internodes. The first one to three internodes are contracted, similarly to most species in the genus, thus making the basalmost flowers to be partially enclosed by the basal bract. Nonetheless, the following internode is considerably and consistently elongated, being commonly three to five times longer than the previous internodes. The subsequent internodes are also contracted, giving the impression that the flowers are also congested at the apex of the inflorescence. This alternation between

contracted and elongated internodes, produces a unique inflorescence architecture in the genus (Fig. 2B).

Affinities. Heteranthera catharinensis is morphologically similar to H. reniformis s.s. due to its petiolate leaves with reniform to broadly cordate blades, pedunculate inflorescences, cincinnus axis glandular-pubescent, glandular-pubescent perianth tube, perianth lobes with a 5+1 arrangement and acute to acuminate at apex, lateral stamens apically barbate, and intrusive-parietal placentation (Horn 1985). It is also superficially similar to H. multiflora s.l. due to its bigger stature, many-flowered inflorescence with few flowers included in the basal bract, and gross floral morphology (Horn 1985). Nonetheless, H. catharinensis can be easily differentiated from all remaining species of Heteranthera by its unique inflorescence architecture (where flowers are congested at the base and the apex of the cincinnus), larger flowers size, numerous flowers on an elongate axis, main axis many times longer that the basal bract, and basal bract with spatulate-mucronate apex. Aside from that, specimens of *H. catharinensis* have been erroneously identified as *H. peduncularis* Benth, due to their robust habit and long inflorescences. However, both species can be easily differentiated based on inflorescence architecture, and pubescence of the tepals and filaments. Furthermore, H. catharinensis has larger floral features, when compared to the remaining species of the H. reniformis complex, including longer perianth lobes and larger anthers. It is also the only species in the complex with externally glabrous perianth lobes, and glabrous central filament and style (Table 1).

#### 2. Heteranthera pumila M.Pell. & C.N.Horn, sp. nov.

urn:lsid:ipni.org:names:77163814-1 Figs 3–5

**Diagnosis.** Similar to *H. reniformis* Ruiz & Pavón due to its petiolate leaves with blades two or more times wider than long, reniform to broadly cordate, cincinnus enclosed by the basal bract, glandular-pubescent cincinnus axis, perianth lobes with a 5+1 arrangement and acute to acuminate at apex, filaments straight, and intrusive-parietal placentation. It differs due to its diminute petiolate leaves  $[3.5-11.8-(13.2) \times 3.2-12.1 \text{ mm}]$ , inflorescences 1-2-(3)-flowered, peduncle densely glandular-pubescent, basal bract glandular-pubescent at base, apex aristate, flowers pale lilac to lilac or light pink, seeds smooth or with 7–9 inconspicuous longitudinal wings.

**Type.** BRAZIL. São Paulo: Piraju, várzea do rio Paranapanema, na divisa com o município de Manduri, 23°07'50"S 49°19'32"W, fl., fr., 10 Oct 2016, M.O.O. Pellegrini & R.F. Almeida 495 (holotype: RB!; isotypes: NBYC!, SPF!, US!).

**Description.** *Herbs* annual or short-lived perennials. *Roots* thin, delicate, unbranched, white. *Stems* repent on the substrate or floating in shallow water, delicate, spongy, rooting at the nodes; internodes 1.7–64.1 mm long, glabrous. *Sessile leaves* not seen. *Petiolate leaves* distichously-alternate, distributed along the stem, floating to emergent; sheaths 2.8–7.5 mm long, glabrous, covered with mucilage, longitudi-



**Figure 4.** Field photos of *Heteranthera pumila* M.Pell. & C.N.Horn. **A** Bog at the Paranapanema river, Piraju, São Paulo, Brazil **B** Habit, showing the dense subpopulation at the muddy shore of the bog **C** Leaf **D** Detail of the apex of the stem, showing the ligule and the inflorescence **E** Detail of the inflorescence, showing the glandular hairs at the peduncle, base of the basal bract and cincinnus **F** Front view of the flower, the shape of the perianth lobes and the color of the nectar guide. Photographs A–E by M.O.O. Pellegrini, F by V. Bittrich.

nally split and light green when mature, ligule 2-parted, surpassing the sheath, 0.2-0.8 mm long, membranous, light green, glabrous, apex triangular; petiole 8.5-82.9 mm long, not inflated, glabrous; blades  $3.5-11.8-(13.2) \times 3.2-12.1$  mm, cordate to broadly cordate to reniform, rarely narrowly cordate, membranous, glabrous, base cordate, margins glabrous, apex acute to obtuse. *Inflorescences* axillary or apparently terminal, reduced to a solitary pedunculate cincinnus; peduncle 0.5-3.4 cm long,

deflexed and submerged in fruit, densely glandular-pubescent; basal bract (spathe)  $0.9-1.9 \times 0.4-0.8$  cm, spathaceous, broadly elliptic, conduplicate, green, glandularpubescent at base, margins hyaline, apex aristate; cincinnus bract absent; cincinnus 1-2-(3)-flowered, all flowers included in the basal bract, when present the third flower always exerted, axis 0.2-1.8 mm long, densely glandular-pubescent. Flowers bisexual, tubular, chasmogamous, sessile, enantiostylous; floral buds narrowly ovoid, light green to lilac or pink, densely glandular-pubescent; perianth tube 4.9-7.3 mm long, light green, densely covered with glandular hairs, lobes 5 superior and 1 inferior, pale lilac to lilac or light pink, lateral superior lobes  $3.6-5 \times 0.8-1.4$  mm, elliptic, base cuneate, apex acute to acuminate, central superior lobe 3.6-4 × 1.7-2.1 mm, ovate to broadly ovate, base obtuse to rounded, slightly involute, apex acute, with a nectar guide at base, yellowish green to green with an upper vinaceous to brown spot, inferior lobe 4.2-4.9 × 0.5-0.8 mm, narrowly elliptic to linear elliptic, base cuneate, apex acuminate; stamens 3, lateral stamens with filaments straight, 1.6-1.8 mm long, pale lilac to light pink, not inflated, apically barbate with eglandular, multi-celled, lilac to pink hairs, anthers  $0.4-0.6 \times 0.3-0.5$  mm, broadly oblongoid to quadrangular, yellow, central stamen with filament straight, 2-2.3 mm long, lilac to pink, not inflated, medially sparsely villose with eglandular, white hairs, anthers  $1.2-1.6 \times 0.3-0.5$  mm, ellipsoid, greyish blue to greyish mauve; ovary  $3.1-3.5 \times 0.3-0.5$  mm, ellipsoid, greyish blue to greyish mauve; ovary  $3.1-3.5 \times 0.3-0.5$  mm, ellipsoid, greyish blue to greyish mauve; ovary  $3.1-3.5 \times 0.3-0.5$  mm, ellipsoid, greyish blue to greyish mauve; ovary  $3.1-3.5 \times 0.3-0.5$  mm, ellipsoid, greyish blue to greyish mauve; ovary  $3.1-3.5 \times 0.3-0.5$  mm, ellipsoid, greyish blue to greyish mauve; ovary  $3.1-3.5 \times 0.3-0.5$  mm, ellipsoid, greyish blue to greyish mauve; ovary  $3.1-3.5 \times 0.3-0.5$ 1-1.2 mm, linear ovoid, glabrous, 1-locular, placentation intrusive-parietal, style gently sigmoid, 4.2-5.1 mm long, lilac to pink, terete, densely villose in the distal portion with eglandular, white hairs, stigma unevenly trilobate, purple to pink, densely glandular-pubescent. Capsule 5.3-7.2 × 1.1-1.9 mm, linear ovoid, glabrous, smooth, light green when immature, light to medium brown when mature; persistent perianth base (anthocarp) smooth, medium to dark brown. Seeds 0.5-0.7 × 0.2-0.3 mm, oblongoid, light brown to yellowish brown, testa smooth, sometimes with 7-9 inconspicuous longitudinal wings; hilum punctate; embryotega dorsal, inconspicuous, without a prominent apicule.

Specimens seen (paratypes). BRAZIL. Minas Gerais: São Sebastião do Paraíso, Fazenda Fortaleza, fl., 20 Apr 1945, A.C. Brade & A. Barbosa 17846 (RB, SP, UNA). Paraná: Guaratuba, Boa Vista, fl., 28 Jan 1964, G. Hatschbach 11078 (MBM); Rio da Divisa, fl., fr., 16 Dec 1971, G. Hatschbach 28523 (MBM, UPCB). **Rio Grande do Sul:** Bom Jesus, Rio Socorro, fl., 19 Feb 2008, Grupo de Estudos Reófitas UHBG 2116 (MBM). Vacaria, vale do Rio Ibitíria, ca. 30 km NE de Vacaria, fl., s.dat., J.C. Lindeman et al. s.n. (ICN9466). **Santa Catarina:** Lages, Santo Antônio, near Passo de Socorro, estrada de rodagem Federal km 67–71, south of Lages, fl., 14 Jan 1957, L.B. Smith & R. Reitz 9959 (HBR, RFA, US). **São Paulo:** Americana, Praia Azul, fl., 2 Mar 1993, Faria 96/16 (UEC). Bálsamo, estrada sentido Bálsamo-Mirassolândia, fl., 30 Jan 1997, A.D. Faria et al. 97/350 (UEC). Dracena, margem do Rio do Peixe, fl., fr., 7 Sep 1995, L.C. Bernacci et al. 2124 (IAC, SP, SPF, UEC). Estrela D'Oeste, SP-320, lago localizado na Fazenda Santo Antônio, lado direito da pista no sentido Estrela D'Oeste-Jales, fl., fr., 30 Jan 1997, L.Y.S. Aona et al. 97/167 (UEC). Igarapava, lagoa localizada



**Figure 5.** Line drawing of *Heteranthera pumila* M.Pell. & C.N.Horn. **A** Habit **B** Detail of the apex of the stem, showing a petiolate leaf, the ligule and a pre-anthesis 2-flowered inflorescence **C** Glandular hair from the inflorescence, perianth tube and lobes **D** Dissected perianth lobes, showing the 5+1 arrangement **E** Lateral stamen. **F** Uniseriate hair from the lateral stamen **G** Central stamen **H** Eglandular hair from the central stamen **I** Gynoecium, showing the stigma **J** Eglandular hair from the style **K** Detail of the inconspicuously winged seed, showing the persistent funiculus with raphid crystals. Illustration by M.O.O. Pellegrini, based on the holotype.

na Fazenda Flor das Frutas, lado direito da pista no sentido Igarapava-Rifaina, na altura do km 16, fl., 15 Jan 1997, A.D. Faria et al. 97/102 (UEC). Ouro Verde, SP-563, km 113, Ponte Nova, Rio do Peixe, fl., 10 Jul 1996, A.D. Faria et al. 96/122 (UEC); loc. cit., fl., fr., 10 Jul 1996, A.D. Faria et al. 96/130 (BOTU, IAC, SP, SPF, UEC). Paulo de Faria, fl., Oct 1994, V.C. Souza et al. 12294 (ESA, IAC, UEC). Pedregulho, rodovia Antônio Giolo, acesso à Estreito, solo encharcado próximo à uma cachoeira, fl., fr., 14 Jan 1997, A.D. Faria et al. 97/64 (UEC). Piraju, várzea do Ribeirão São Bartolomeu, fl., fr., 15 May 1996, E.L.M. Catharino et al. 2090 (PMSP). Riolândia, brejo localizado em estrada de terra no sentido Riolândia-Paulo de Faria, fl., 29 Jan 1997, L.Y.S. Aona et al. 97/152 (UEC). Santa Rita do Passa Quatro, rodovia Anhanguera, km 239, Sítio Aubiri, fl., 13 Jan 1997, A.D. Faria et al. 97/20 (UEC). São José do Rio Preto, represa, fl., 25 Nov 1965, G. Marinis & E.M.P. Martins 20 (FUEL, SJRP, SP); Estação Experimental de Zootecnia de São José do Rio Preto, fl., 28 Dec 1977, M.A. Coleman 220 (SP). São Pedro do Turvo, 8 km da estrada em direção à Marília, desvio em estrada de terra ca. 3.5 km, 49°70'W 22°48'S, est., 9 Dec 1994, M.C.E. Amaral & V. Bittrich 94/48 (UEC). Sud Mennucci, distrito de Bandeirantes D'Oeste, fl., 4 Aug 1995, M.R. Pereira-Noronha et al. 1552 (SP). Teodoro Sampaio, margem do lago ao lado da estrada Teodoro Sampaio-Planalto, ca. Km 11.5, fl., Oct 1997, L.Y.S. Aona et al. 97/241 (UEC).

**Etymology.** The epithet means "small", making allusion to the small stature of the new species, especially its diminute leaf blades.

**Distribution, habitat and ecology.** *Heteranthera pumila* is endemic to the Paraná, Uruguay, and Southeastern Atlantic watersheds, in the Atlantic Forest domain. It is restricted to Brazil, in the states of Minas Gerais, São Paulo, Paraná, Santa Catarina and Rio Grande do Sul (Fig. 2), growing on open marshy areas and slow water environments along the Paraná, Paranapanema and Rio Grande rivers (and their respective tributaries), from 700 to 1,800 meters above the sea level. It is very likely that *H. pumila* also reaches the state of Mato Grosso do Sul. Nonetheless, we have been unable, so far, to find any vouchers from this state in the visited herbaria.

**Phenology.** *Heteranthera pumila* blooms throughout the year, with flowering peaks during the wet season, and was found in fruit from September to October and from January to March.

**Conservation status.** *Heteranthera pumila* is widely distributed across the upper Paraná, Uruguay, and Southeastern Atlantic watersheds, with a wide EOO (ca. 318,815.754 km<sup>2</sup>) which would render this species as Least Concern. On the other hand, its AOO is considerably smaller (ca. 88.000 km<sup>2</sup>), which would render *H. pumila* as Endangered. The Paraná, Uruguay, and Southeastern Atlantic watersheds cover eight Brazilian states (Distrito Federal, Goiás, Mato Grosso do Sul, Minas Gerais, Rio Grande do Sul, Santa Catarina, São Paulo, and Paraná), embedded in the Atlantic Forest and Cerrado domains. Its main tributaries are the Iguaçu, Paranaíba, Paranapanema, Rio Grande and Tietê rivers. It possesses the greatest energy generation potential in Brazil, with 176 active hydropower plants, the largest being Itaipu, Furnas, Porto Primavera and Marimbondo. Nonetheless, all the major rivers are currently saturated

with hydropower plants, and new projects aim to occupy the smaller tributaries, in order to fulfil the growing energy demand in the region (ANA 2002). Almost all the known subpopulations of *H. pumila* coincide with areas currently flooded, and might already have gone extinct, due to the construction of the aforementioned water dams. The few extant subpopulations vary from medium to large, with many clones and mature individuals. Nonetheless, they are currently strongly threatened due to pollution, deforestation, and by ongoing and future constructions of new hydropower plants. Thus, following the IUCN recommendations (IUCN 2001), *H. pumila* should be considered as Critically Endangered [CR, A2acd+B1b(ii, iii, iv)+B2ab(ii, iii, iv)+C1+E].

**Morphological notes.** Extensive morpho-ecological studies (Horn 1983, 1988) have shown that *Heteranthera* species are highly polymorphic vegetatively, as an adaptation to submersion and variations in water level. The same can be observed in the new species herein described, that despite the diminute general stature, may sometimes possess extremely long petioles and peduncles. *Heteranthera pumila* has been kept in cultivation by the senior author, and even under different environmental conditions, little change was observed in the species' vegetative morphology. Nevertheless, when cultivated in aquariums with different water depths, the change in the length of petioles and peduncles could be observed in less than a week. The already existing structures elongated in order to keep the leaf blades floating and flowers emerged, and the subsequently produced petiolate leaves and inflorescences were considerably longer than the previous ones of the same individual.

Affinities. Heteranthera pumila is morphologically similar to H. reniformis due to its petiolate leaves with blades two or more times wider than long, cordate to reniform, rarely narrowly cordate, cincinnus enclosed by the basal bract, glandularpubescent cincinnus axis, perianth lobes with a 5+1 arrangement with acute to acuminate apex, filaments straight, lateral stamens apically barbate, central stamen basally sparsely villose, and intrusive-parietal placentation (Horn 1985). It is also similar to H. multiflora due to its petiolate leaves with blades two or more times wider than long, cordate to broadly cordate to reniform, rarely narrowly cordate, perianth lobes with a 5+1 arrangement and acute to acuminate apex, and straight filaments (Horn 1985). Nonetheless, it can be easily differentiated from all remaining species of Heteranthera by its petiolate leaves with diminute blades [i.e. 3.5- $11.8-(13.2) \times 3.2-12.1$  mm], inflorescences 1-2-(3)-flowered, peduncle densely glandular-pubescent, basal bract basally glandular-pubescent with aristate apex, and seeds smooth or with 7–9 inconspicuous longitudinal wings (Fig. 5). The only other species in Heteranthera that possesses seeds not conspicuously winged is H. gardneri, in which the wings are very short, giving the seeds a striate appearance. Nevertheless, in H. pumila, the testa is almost smooth, with the stripes representing only pigmentation. All the remaining species of Heteranthera possess seeds with 8-19 conspicuous longitudinal wings (Horn 1985; Table 1).

# Key to the species of Heteranthera in Brazil

1	Ligule with several filiform (leaf-like) projections, sessile leaves appearing ver-
	ticillate, blades filiform to acicular; flowers non-enantiostylic, stamen 1, stami-
	nodes commonly absent, if present consisting of a filiform projection
-	Ligule 2-parted, sessile leaves clearly distichously or spirally-alternate, blades
	linear oblong to narrowly obovate; flowers enantiostylic, stamens 3, stami-
	nodes generally absent, if present not filiform2
2	Sessile leaves persistent in mature plants, petiolate leaves rarely produced,
	floating, blades linear oblong to narrowly obovate
_	Sessile leaves marcescent in mature plants, rarely persistent, petiolate leaves
	always produced, floating or emersed, blades narrowly cordate to broadly cor-
	date to reniform or broadly ovate to broadly elliptic4
3	Inflorescences 5-12-flowered, glandular-pubescent when emersed, basal
	bract (spathe) with aristate apex; perianth yellow, rarely lilac or white
_	Inflorescences (1–)2-flowered, always glabrous, basal bract (spathe) with mu-
	cronate to retuse apex, perianth lilac to purple
4	Petiolate leaves typically with blades longer than wide, base rounded to au-
	riculate; perianth lobes with a 3+3 arrangement, nectar guide yellow to bright
	yellow, filaments sigmoid, glandular-pubescent, placentation axial5
_	Petiolate leaves typically with blades wider than long, base conspicuously cor-
	date; perianth lobes with a 5+1 arrangement, nectar guide yellowish green to
	green, filaments straight, barbate or villose with eglandular hairs, sometimes
	glabrous, placentation intrusive-parietal7
5	Sessile leaves abaxially green; inflorescence (1-)2-flowered, spathe flattened,
	slightly to distinctly falcate, narrowly ovate to ovate, apex obtuse; perianth
	lobes obovate to broadly elliptic, three superior lobes without a white band at
	base H. oblongifolia Mart. ex Schult. & Schult.f.
-	Sessile leaves abaxially white; inflorescence 1-flowered, spathe cylindrical,
	straight, linear to narrowly obovate, apex acute to acuminate; perianth lobes
	oblong to linear elliptic, three superior lobes with a white band at base6
6	Leaf blades rounded to oblong, cordate to truncate at base; floral tube glan-
	dular-pubescent, perianth lobes slightly to distinctively falcate, upper central
	perianth lobe auriculate near base; pollen dispersed in monads
	<i>H. rotundifolia</i> (Kunth) Griseb.
-	Leaf blades oblong to ovate, truncate to cuneate at base; floral tube glabrous,
	perianth lobes flat, upper central perianth lobe not auriculate; pollen dis-
	persed in tetrads

7 Petiolate leaves with smaller blades, 3.5-11.8-(13.2) × 3.2-12.1 mm; inflorescences 1-2-(3)-flowered, basal bract (spathe) with aristate apex; seeds smooth or with 7–9 inconspicuous longitudinal wings ..... Petiolate leaves with larger blades,  $12-75 \times 10-81$  mm; inflorescences 3-30-flowered, basal bract (spathe) with acute to mucronate, rarely spatulate-Petiolate leaves glandular-pubescent when emersed; inflorescence sessile, 8 10-30-flowered, flowers opening over several days, peduncle densely glandular-pubescent; central superior perianth lobe without a nectar guide, apex Petiolate leaves always glabrous; inflorescence pedunculate, 3-8-(9-17)-flowered, flowers opening in one or two days, peduncle glabrous; central superior perianth lobe with a nectar guide, apex acute to acuminate......9 9 Inflorescences with flowers condensed at the base and apex of the cincinnus, 6-17-flowered, basal bract with spatulate-mucronate apex; perianth lobes externally glabrous, central superior perianth lobe 6.6-9.2 mm long; central stamen with filament glabrous, style glabrous ..... Inflorescences with flowers evenly distributed on cincinnus, 3–13-flowered, basal bract with acute to mucronate apex; perianth lobes externally glandularpubescent, central superior perianth lobe 2.3-5 mm long; central stamen with filament villose or barbate, style villose.....10 10 Leaf blade cordate (length/width ~ 1); peduncle < 1 cm long, cincinnus main axis glabrous; all filaments barbate with long, purple hairs ..... Leaf blade commonly reniform (length/width mostly < 1); peduncle > 1 cm long, cincinnus main axis glandular-pubescent; lateral stamens barbate with long hairs, central stamen sparsely villose, hairs white ..... 

# Discussion

## Inflorescence morphology and terminology in Pontederiaceae

The inflorescence in Pontederiaceae, has traditionally been regarded as consisting of panicles and spikes, or more rarely, reduced to one-flowered racemose inflorescence (Lowden 1973; Dahlgren et al. 1985; Horn 1985; Rosatti 1987; Cook 1998). Nonetheless, some studies have described the inflorescence in the family as being thyrsoid, with an indeterminate main axis and cymose branches (Cook 1989; Richards and Barrett 1984; Pellegrini 2017). More specifically, Richards and Barrett (1984), based on developmental studies in *E. paniculata* (Spreng.) Solms, described the cymose secondary branches as representing cincinni with greatly reduced bracteoles. This is consistent with the commonly zig-zag or scorpioid pattern observed in many Pontederiaceae inflorescences (Pellegrini and Horn, pers. obs.), the occurrence of mirror-image flowers in *H. gardneri* (Hook.f.) M.Pell. (which is comparable to the 2-flowered cincinni with mirror-image flowers of Marantaceae; Kirchoff 1985), and the predominant occurrence of cincinni and other cymose inflorescences in Commelinid Monocots (Fahn 1953; Uhl 1969; Kirchoff 1985; Panigo et al. 2011; Kellogg et al. 2013; Remizowa et al. 2013; Stützel and Trovó 2013). Thus, the inflorescence in the family is to be regarded as thyrsoid, being composed of a many-branched thyrse, with spirally arranged cincinni in *Pontederia s.l.*, and reduced to a solitary cincinnus in *Heteranthera s.l.* Cincinni bracts and bracteoles are greatly reduced in most species, being not observable to the naked eye, but consisting of ephemeral rudimentary ridges under the scanning electron microscope (Richards and Barrett 1984). Bracteoles are only macroscopically visible in *E. meyeri* A.G.Schulz, a species closely related to *E. paniculata*, being a key character in differentiating both taxa (Horn 1998).

Inflorescence architecture, has a great unexplored taxonomic potential in the Pontederiaceae, also supporting the family's bigeneric circumscription, proposed by Pellegrini (2017). Aside from that, different inflorescence patterns seem to support different lineages within the family's two major clades. In Heteranthera s.l., the reduction to 1-2-flowered inflorescence seems to be, at least, partially correlated with a reversal from intrusive-parietal placentation to axial placentation, and sigmoid filaments in the H. limosa (Sw.) Willd. species group [i.e. H. limosa, H. lutea, H. oblongifolia Mart. ex Schult. & Schult.f., and H. rotundifolia (Kunth) Griseb.]. Furthermore, in the permanently submersed species of Heteranthera [i.e. H. dubia (Jacq.) MacMill., H. gardneri, and H. zosterifolia Mart.], reduction to 1-2-flowered inflorescence seems to be correlated with the partial or complete loss of petiolate leaves, with the reversion from zygomorphic to actinomorphic flowers, and the loss of enantiostyly. In Pontederia s.l., E. meyeri and E. paniculata can be readily differentiated from the remaining species on the clade by their elongated cincinni, and inflorescence erect at post-anthesis. In Monochoria C.Presl, the cincinni can range from obviously spirally arranged to fasciclelike, and from one to several-flowered, being very useful in species delimitation. Furthermore, great reduction is observed in the inflorescences of *E. diversifolia* (Vahl) Urb. and E. natans (P.Beauv.) Solms, with thyrsi always producing 1-flowered cincinni, and the number of cincinni being useful in differentiating both species. Finally, in Pontederia s.s., the inflorescence is a spike-like thyrse, due to the increase in the number of cincinni, contraction of the cincinni peduncle and internodes, and finally, due to the shortening of the main florescence internodes.

#### Heteranthera reniformis species complex and H. multiflora subcomplex

As aforementioned, *H. reniformis s.l.* is an economically important, but poorly understood weed. This species complex can be easily characterized by its petiolate leaves typically with



Figure 6. Heteranthera reniformis Ruiz & Pavón complex. A–B H. multiflora (Griseb.) C.N.Horn s.l., from Missouri, USA: A Habit B Inflorescence C–D H. peduncularis Benth., from Michoacán, Mexico:
C Habit D Inflorescence E–F H. reniformis Ruiz & Pavón s.s., from Bahia state, Brazil: E Habit F Inflorescence. Photos A–B by Steve R. Turner, C–D by C.N. Horn, and E–F by M.O.O. Pellegrini

blades wider than long, base conspicuously cordate; flowers opening in one or two days; perianth lobes with a 5+1 arrangement and acute to acuminate apex, nectar guide yellowish green to green; straight filaments, barbate or villose with eglandular hairs, sometimes glabrous; and intrusive-parietal placentation (Figs 1, 2, 4–6). The group is currently composed of five neotropical species: *H. catharinensis* (Figs 1, 2), *H. multiflora s.l.* (Fig. 6A, B), *H. peduncularis* (Fig. 6C, D), *H. pumila* (Figs 4, 5), and *H. reniformis s.s.* (Fig. 6E, F). Characters such as inflorescence architecture, pubescence, and flower morphology are key in species delimitation (Pellegrini and Horn, pers. obs.).

Despite our present contribution to the H. reniformis species complex, further studies are still necessary to better understand some polymorphic species. Heteranthera multiflora s.l. is widely but disjunctively distributed, occurring in the United States, Venezuela, and widespread across Brazil, Argentina, and Paraguay (Horn 1985). It is currently circumscribed as comprising plants with many-flowered inflorescences with most flowers exerted from the basal bract, glabrous cincinnus axis, and stamens bearded with long, uniseriate, purple hairs (Horn 1985; Horn 2002; Horn and Pellegrini, pers. obs.). However, throughout this species' range, it is possible to recognize five different morphotypes: (1) specimens with petiolate leaf blades longer than wide, smaller sessile inflorescences, with most flowers included in the basal bract, flowers white to pale lilac, and distributed along the Atlantic Coast of the United States; (2) specimens with round petiolate leaf blades, longer sessile inflorescences, with few flowers included in the basal bract, flowers lilac to blue with darker perianth lobes base, and distributed in the Great Plains of the United States; (3) a sole peculiar collection from northern Venezuela; (4) specimens with petiolate leaf blades longer than wide, sessile inflorescences, lilac flowers, and distributed in Northeastern Brazil (i.e. states of Alagoas, Bahia, Paraíba, Pernambuco and Sergipe); and (5) specimens with petiolate leaf blades as wide as long, pedunculate inflorescences, white flowers, and distributed from Northern, Northeastern and Central-Eastern Brazil (i.e. states of Alagoas, Bahia, Maranhão, Mato Grosso do Sul, Pará, Rondônia, and Tocantins) to Southeastern Brazil (i.e. states of Espírito Santo, Minas Gerais, and Rio de Janeiro), Argentina, and Paraguay (Horn 1985; Horn and Pellegrini, pers. obs.). A new circumscription for H. multiflora s.l., based on macromorphology and morphometric analyses, is currently in the works (Horn and Pellegrini, in prep.), and will shed new light in this poorly understood taxon.

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**RESEARCH ARTICLE** 



# Semenovia gyirongensis (Apiaceae), a new species from Xizang, China

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#### Abstract

Based on morphology and molecular data, a new species *Semenovia gyirongensis* Q.Y.Xiao & X.J.He, from Gyirong County, Xizang, China, is described and illustrated. It is morphologically most similar to *S. malcolmii* (Hemsley & Pearson) Pimenov, but differs in its cylindric much-branched root, intensively branching long underground caudex with distinct nodes, narrowly ovate to ovate terminal leaf lobes, oblong bracts with obtuse-rounded or cuneate apex.

#### Keywords

Apiaceae, new species, pollen, Qinghai-Tibetan Plateau, Semenovia, taxonomy

## Introduction

*Semenovia* Regel & Herder (Apiaceae, tribe Tordylieae), an endemic Asiatic genus, occurs in southwest, central and east Asia, with its center of diversity in the Pamir mountains (Shen 1992; Pimenov and Leonov 1993; Pu and Watson 2005; Ukrainskaja 2015). Most species of *Semenovia* are narrow endemics and grow mainly in the mid-elevation to highland areas of mountains (Ukrainskaja et al. 2013; Ukrainskaja 2015). The latest revision of *Semenovia* was conducted by Ukrainskaja et al. (2013), who recognized 29 species. There are 6 species of *Semenovia* in China, two of which are endemic to Qinghai-Tibetan Plateau (QTP) (Ukrainskaja et al. 2013). *Semenovia* is a perennial herb with pinnate leaves, entire or branched caudex, unequal (outer ones are

larger) or subequal outer and inner petals, small bracts and bracteoles, well developed styles, thinly and narrowly winged marginal ribs, filiform vittae, solitary vittae per vallecular and two (rarely four) on commissural surface (Regel and Herder 1866; Mandenova 1959; Alava 1987; Pu and Watson 2005). Caudex states (underground, overground or emergent; unbranched or branched; short or long branches) are regarded as the most important diagnostic characters within the genus *Semenovia* (Ukrainskaja et al. 2013; Ukrainskaja 2015).

According to morphological data, the genus *Semenovia* clearly differs from closely related genera *Tordyliopsis* DC. (well-developed, broad leafy bracts and bracteoles), *Zosima* Hoffm. (strongly inflated and broadly winged marginal ribs, dorsal vittae occupying furrows completely), *Kandaharia* Alava (very short styles, up to 0.5 mm long, strongly inflated and broadly winged marginal ribs, numerous commissural vittae), and *Pastinacopsis* Golosk (vallecular and commissural vittae obsolete) (Mandenova 1959; Alava 1987; Pimenov et al. 2000; Menemen and Jury 2001; Pu and Watson 2005; Ukrainskaja et al. 2013).

During examining specimens of *Semenovia*, we encountered one collection (*Z. Y. Wu et al. 75-0676*, stored in HNWP, KUN and PE), which was collected from Gyirong County, Xizang, China and was unable to identify as any described species. In August 2016, we carried out field investigation to the exact locality and gathered both flowering and fruiting plant from the natural population. After thoroughly consulting relevant literatures (e.g. Mandenova 1959; Alava 1987; Vinogradova and Kamelin 1986; Ukrainskaja et al. 2013; Ukrainskaja 2015) and herbarium specimens, as well as comparing this taxon with all described species within the genus, we come to the conclusion that the specimens from Gyirong represent a hitherto undescribed species. Herein a new name *Semenovia gyirongensis* is proposed, and detailed descriptions and comments of this new species, as well as comparisons with its morphologically similar species are given.

#### Material and methods

#### Specimen examinations, field investigations and morphology observations

Related specimens deposited in C, CDBI, HNWP, K, KUN, NAS, PE, SZ, XJA and XJBI were studied. Protologues and images of type specimens were gathered from-Tropicos (http://www.tropicos.org), JSTOR Global Plants (http://plants.jstor.org) and the International Plant Names Index (http://www.ipni.org). Herbarium acronyms followed Thiers (2016).

Sampling was conducted from type localities of *S. gyirongensis* (Gyirong County, Xizang) and *S. malcolmii* (Shuanghu, Nyima County, Xizang) during 2015–2016. Photographs in the field were made using a Nikon D7100 camera. The measurements of the morphological features were conducted using a vernier caliper. Mericarps were photographed using stereomicroscope Nikon SMZ 25 (Japan). Fruits from formalde-

hyde-acetic acid-alcohol (FAA) preserved material were used in the anatomical study. Pollen was examined from anthers collected directly in the field. The pollen grains were mounted on clean aluminum stubs using conducting carbon adhesive tabs, coated and then scanned with a JSM-7500F scanning electron microscope (SEM). General terminologies for this study followed Kljuykov et al. (2004). Voucher specimens were deposited in the herbarium of Natural History Museum of Sichuan University (SZ).

#### DNA extraction, amplification and sequencing

Total genomic DNA was extracted from silica gel-dried leaves and herbarium materials according to the protocols of plant genomic DNA kit (Tiangen Biotech, Beijing, China). The internal transcribed spacer (ITS) and external transcribed spacer (ETS) of nuclear ribosomal DNA (nrDNA) were used for phylogenetic inference based on the previous study (Logacheva et al. 2010). The primer pairs ITS4 / ITS5 (White et al. 1990) and 18S-ETS (Baldwin and Markos 1998) / Umb-ETS (Logacheva et al. 2010) were used to amplify the ITS and ETS regions, respectively. Amplification was carried out in a 30 $\mu$ L volume with 2  $\mu$ L plant total DNA, 10  $\mu$ L ddH<sub>2</sub>O, 1.5  $\mu$ L forward primer, 1.5 µL reverse primer and 15 µL 2 × Taq MasterMix (cwbio, Beijing, China). PCR cycling profile included a denaturing step at 95 °C for 4 min, followed by 35 cycles of 45 s at 95 °C, annealing at 54 °C for 45 s and extension at 72 °C for 1 min, with a final extension for 10 min at 72°C. Sequencing (both directions) was carried out using the amplification primers on an ABI 3730 sequencer at the Beijing Genomics Institute (BGI) in Beijing, China. All newly reported sequences were deposited in GenBank and accession numbers along with sample codes and localities were given in Suppl. material 1: Table S1.

#### Sequence alignment and phylogenetic analysis

62 accessions were obtained from GenBank for the nrDNA ITS and ETS, and 4 were newly sequenced for this study (Suppl. material 1: Table S1), representing 56 species from 17 genera of tribe Tordylieae (plus the new species *S. gyirongensis*, a total of 22 species of *Semenovia* were included) and 2 species of *Conium*. Sequence data for the ITS 5.8S region were excluded from the analysis because they were unavailable for many previously published taxa. *Conium maculatum* L. and *Conium sphaerocarpum* Hilliard & Burtt were selected as outgroups (Ajani et al. 2008; Banasiak et al. 2013).

SeqMan (Burland 2000) was used to edit DNA sequences and obtain consensus sequences. DNA sequences were aligned with ClustalX ver. 2.1 (Larkin et al. 2007) and then adjusted manually using MEGA7 (Kumar et al. 2016). Topological incongruence the partition between ITS and ETS was tested using the incongruence length difference (ILD) test (Farris et al. 1994) implemented in PAUP\* version 4.0b10 (Swofford 2003). The two markers were then combined and analyzed using Bayesian Inference

(BI), Maximum Likelihood (ML), and Maximum Parsimony (MP). Pairwise nucleotide differences of unambiguously aligned positions were determined from the distance matrix option in PAUP\* (Swofford 2003). The BI analysis was performed in MrBayes version 3.2 (Ronquist et al. 2012). MrModeltest version 2.2 (Nylander 2004) was used to select a best-model (GTR+G) of nucleotide substitution. Four simultaneous runs were performed using Markov chain Monte Carlo (MCMC) simulations for 20 million generations, starting from a random tree and sampling one tree every 1000 generations. The convergence and effective sample size (ESS) of each replicate were checked using Tracer v. 1.6.0 (Rambaut et al. 2013). The first 25% of obtained trees were discarded as burn-in and the remaining were used to calculate a 50% majority-rule consensus topology and posterior probability (PP) values. For the ML analysis, phylogenetic reconstruction was performed using RAxML-HPC BlackBox ver. 8.2.10 under the GTR+G nucleotide substitution model and 1000 rapid bootstraps on the CIPRES Science Gateway ver. 3.3 (Miller et al. 2010). The MP tree was obtained using the programs PAUP\* version 4.0b10. Heuristic searches were replicated 1000 times with random taxon addition sequences, tree bisection-reconnection (TBR) branch swapping, and setting the maximum number of trees to 10,000. Bootstrap values were calculated from 1,000,000 replicate analyses using 'fast' stepwise-addition of taxa and only those values compatible with the majority-rule consensus tree were recorded.

#### **Result and discussion**

#### Morphological analysis

*S. gyirongensis* is a perennial polycarpic herb with very dense ribbon shaped hairs throughout, having cylindric much-branched roots, intensively branching long underground caudex with distinct nodes, covering rigid imbricate perished leaf sheaths and petioles, simple or sparingly branched stems, 2–3-pinnate leaves, narrowly ovate to ovate terminal leaf lobes, oblong bracts (minute), narrowly long-ovate bracteoles (2–4 mm), 5–10 rays, long styles (2.5–3 mm), mericarps elliptic or broadly elliptic, 4–7 mm long, thinly and narrowly winged marginal ribs, 4 dorsal vittae, and 2 commissural vittae (reaching 1/4 mericarp length) (Fig. 1, Fig. 2A1–A6). This description corresponds very well to the general characteristics of *Semenovia* (Regel and Herder 1866; Mandenova 1959; Alava 1987; Pu and Watson 2005), indicating that the new putative species under *Semenovia* is well justified.

These characters of *S. gyirongensis* allow for easy discrimination from morphologically similar species *S. malcolmii* (fusiform unbranched roots, unbranched to muchbranched, short overground or emergent caudex, without distinct nodes, linear to narrowly long-ovate terminal leaf lobes and linear to narrowly ovate bracts, apex acute, Fig. 2B1–B6 and Table 1), *S. pamirica* (much dichotomously branched stems, 2–4 rays, and commissural vittae reaching 3/4 mericarp length, Suppl. material 1: Fig. S1D



Figure I. Semenovia gyirongensis A–B Habitat C Abaxial surface of primary pinnae D Basal leaf sheaths
E Middle-upper cauline leaf sheaths F Rays G Adaxial surface of primary pinnae, showing hairs H Compound umbel I Umbellule J Bracts K Calyx teeth and stylopod L Infructescence M Dorsal side of mericarp N Commissural side of mericarp O Cerebroid ornamentation on equatorial plane of pollen grain P Tricolporate Q Rounded pollen polar ends.



Figure 2. Diagnostic morphological characters of *Semenovia gyirongensis* (AI–A6) in comparison to the similar species *Semenovia malcolmii* (BI–B6) AI–BI Habitat A2 Oblong minute bracts, apex obtuse-rounded or cuneate B2 linear to narrowly ovate bracts, apex acute A3 narrowly ovate to ovate ultimate leaf lobes B3 linear to narrowly long-ovate ultimate leaf lobes A4 Long-branched underground caudex with distinct nodes B4 Short-branched overground or emergent caudex A5 Cylindric and much-branched root B5 Fusiform and unbranched root A6 Ellipsoidal pollen grains B6 Equatorially constricted pollen grains.

Table I. Main moi	phological difference between <i>Sem</i>	enovia gyirongensis and its morphologic	cal allies.	
Charactes	S. gyirongensis	S. malcolmii	S. pamirica	S. vachanica
Hairs	very dense	sparse or dense	dense	dense
Root	cylindric, much-branched	fusiform, unbranched	incomplete material	incomplete material
Caudex	underground, much-branched, long branches, with distinct nodes	overground or emergent, unbranched to much-branched, short branches, without distinct nodes	overground or emertent, much- branched, short branches, without distinct nodes	underground, much-branched, long branches, without distinct nodes
Stem	simple or sparingly branched	simple or sparingly branched	much dichotomously branched	without branches or with a single branch above
Basal leaves	2–3-pinnate	2–3-pinnatisect	simple-pinnate	pinnatisect
Terminal leaf lobes	0.5–2 mm, narrowly ovate to ovate	0.7-5.7 mm, linear to narrowly long- ovate	2–4 mm, linear	0.5–2 mm, toothed
Rays	5-10, 1-2  cm	4-12, 0.5-3.5 cm	2-4, 1.5-2.5 cm	2-5, 1.5-2  cm
Bracts	minute, 0.4–1.5 mm oblong, apex obtuse-rounded or cuneate	2–8 mm, linear to narrowly ovate, apex acute	2–4 mm ovate-narrowly ovate, apex acute, margin white-scarious	4–6 mm, linear-narrowly ovate, apex almost filiform, white-margined
Commissural vittae	1/4 length of mericarp	1/4 length of mericarp to base	3/4 length of mericarp	short, not reaching fruit base

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and Table 1), *S. vachanica* Ukrainskaja & Kljuykov (pinnatisect leaves, toothed terminal leaf lobes, linear-narrowly ovate bracts, apex almost filiform, Table 1) and the rest species of *Semenovia* not included in the phylogeny *S. pulvinata* Pimenov & Kljuykov (plants forming dense hemispheric cushion), *S. dissectifolia* Ukrainskaja & Kljuykov (soft fibrous remnant sheaths, vallecular vittae solitary to paired), *S. imbricata* Ukrainskaja & Kljuykov (alternately branched stems, commissural vittae almost reaching mericarp bases), *S. propinqua* (Aitch. & Hemsl.) Manden. (glabrous, much-branched stems, narrowly lanceolate bracts with membranous margins), *S. suffruticosa* (Freyn & Bornm.) Manden. (overground caudex, pinnate leaves, broadly triangular terminal leaf lobes), *S. heracleifolia* (Wolff) Hedge & Lamond (stems glabrous, basal leaves few, vittae reaching mericarp bases) and *S. macrocarpa* (Rech. f. & H. Riedl) Alava (2–3 rays, mericarps 8–10 mm long) (Alava 1987; Ukrainskaja et al. 2013).

#### Phylogenetic analysis

The matrix of combined nrDNA ITS and ETS data had an aligned length of 775 positions, of which 310 were parsimony informative, 283 were constant, and 182 autapomorphic characters. The results of the ILD test for those 66 accessions common to both ITS and ETS datasets revealed that these loci yield significantly different phylogenetic estimates (P = 0.001). However, numerous reports indicated that the results of an ILD test do not adequately assess data combinability (e.g. Yoder et al. 2001; Barker and Lutzoni 2002; Hipp et al. 2004). Despite the incongruence of these data, the topologies of the ITS- and ETS-derived trees did not conflict. Meanwhile, the analysis of the combined dataset using ML, MP and BI yielded similar trees and had higher MP Bootstrap values (MP-BS), ML Bootstrap values (ML-BS) and BI posterior probabilities (BI-PP). The Bayesian majority rule consensus tree based on combined analysis was presented in Fig. 3. ML-BS, MP-BS and BI-PP values were showed along the branches.

Based on our reconstructed phylogeny, 5 major evolutionary clades (*Cymbocarpum* clade, *Heracleum* sensu stricto clade, *Semenovia* clade, *Tetrataenium* I clade and *Tetrataenium* sensu stricto clade) of tribe Tordylieae were identified (Fig. 3), which was consistent with previous works (Logacheva et al. 2010). The *Semenovia* clade was well supported (ML-BS 89%; MP-BS 61%; BI-PP 1.00) comprising *Zosima, Semenovia* and the monotypic genera *Tordyliopsis, Pastinacopsis* and *Kandaharia* and could be divided into three sub-clades (A, B, and C). The subclade B was strongly supported (ML-BS 95%; MP-BS 73%; BI-PP 1.00), but subclade A (ML-BS 54%; MP-BS <50%; BI-PP 0.87) and subclade C (ML-BS <50%; MP-BS <50%; BI-PP 0.79) were weakly supported (Fig. 3). The monotypic genera *Pastinacopsis* fell into sub-clade A with 6 species of *Semenovia*, while two species of *Zosima* and the monotypic genera *Kandaharia* intermixed within sub-clade C with the largest number of *Semenovia* taxa (12 species). Subclade B consisted of *Tordyliopsis brunonis* DC., *S. gyirongensis, S. pamirica* (Lipsky) Mandenova and *S. thomsonii* (C.B.Clarke) Mandenova (Fig. 3). Within sub-clade B, three accessions of *S. gyirongensis* formed a well monophyletic clade (MP-BS 100%;



**Figure 3.** Phylogenetic tree inferred from tribe Tordylieae and outgroups of combined ITS/ETS dataset based on Bayesian inference (BI) method. The names of the major clades follow the study of Logacheva et al. (2010). Support values only those greater than 50% ML-BS, 50% MP-BS and 0.5 BI-PP are shown along the branches. Numbers on the branches indicated ML-BS/ MP-BS/ BI-PP, respectively. Asterisks denoted (\*) the values of 100/100/1.00 for ML-BS/ MP-BS/ BI-PP. Dshes (-) indicated ML-BS and MP-BS values <50%.

ML-BS 100%; BI-PP 1.00), as a sister group to *S. pamirica* (Fig. 3). The genus *Semeno-via* is not monophyletic based on these phylogenies (and neither is *Zosima*) (Fig. 3). The circumscription of all genera within the *Semenovia* clade should be revised, but this is out of the scope of the present study.

In the concatenated data sets, pairwise sequence divergence estimates for the examined taxa of the *Semenovia* clade ranged from 0.00% (between *S. gyirongensis* JL1 and JL3) to 8.01% (between *Semenovia vaginata* Pimenov and *Zosima absinthifolia* Link) with a mean value 4.4%. Sequence comparisons between the three accessions of *S. gyirongensis* resulted in low pairwise divergence values of 0% to 0.14%, but *S. gyirongensis* and its closely related species *S. malcolmii* (4.96–5.10%), *S. pamirica* (4.16–4.3%), *T. brunonis* (3.45–3.59%) and *S. thomsonii* (3.85–3.99%) yielded relatively high sequence divergence value (Suppl. material 1: Table S2), supporting the hypothesis that *S. gyirongensis* is a distinct taxon.

#### Geographical distribution

Geographically, *S. gyirongensis* is close or adjacent to *T. brunonis, S. pamirica, S. mal-colmii* and *S. thomsonii* but do not overlap (Suppl. material 1: Fig. S2). *S. gyirongensis* is only known from the type locality, Gyirong County, Xizang, China. *T. brunonis* is distributed in Bhutan, Nepal, India (Sikkim, Himachal Pradesh, Uttarakhand) and also in South Xizang, but grows in subalpine moist dwarf scrubs, among shrubs and boulders (Pu and Watson 2005; Kumar et al. 2014). *S. pamirica* is confined to Pamiro-Alai and Central Asia (Shishkin 1968). *S. malcolmii* occurs in the QTP and adjacent regions, but never in Gyirong County. *S. thomsonii* is in Jammu, Kashmir and in whole India (Ukrainskaja et al. 2013) (Suppl. material 1: Fig. S2).

#### Conclusion

Taking the morphology, molecular and geographical distribution evidences into consideration, it is thus clear that *S. gyirongensis* should be recognized as a new, distinct species of *Semenovia*.

Taxonomic treatment

*Semenovia gyirongensis* Q.Y.Xiao & X.J.He, sp. nov. urn:lsid:ipni.org:names:77163815-1 Figure 1, 2A1–A6, 4, Suppl. material 1: Fig. S1A–B, S3

**Type. China:** Xizang, Gyirong County, Woma village, near Longda, 28°45.01'N, 85°18.22'E, 4023 m, 30 July 2016, *xqy-20160730-01* (holotype SZ; isotypes SZ).

**Diagnosis.** Semenovia gyirongensis is most similar to S. malcolmii, but can be easily distinguished by its roots (cylindric much-branched vs. fusiform unbranched), caudex (intensively branching, long, underground, with distinct nodes vs. unbranched to much-branched, short, overground or emergent, without distinct nodes), terminal leaf lobes (narrowly ovate to ovate vs. linear to narrowly long-ovate), and bracts (oblong, apex obtuse-rounded or cuneate vs. linear to narrowly ovate, apex acute).

It is also similar to the closely related species *S. pamirica*, but differs in stems (simple or sparingly branched vs. much dichotomously branched), rays (5–10 vs. 2–4), and commissural vittae length (reaching 1/4 mericarp length vs. reaching 3/4 mericarp length).

Description. Herbs perennial, polycarpic, grayish-green, 8-38 cm high, very dense ribbon shaped hairs throughout, with intensively branching long (up to 40 cm) underground caudex having distinct nodes (rooting at the nodes). Root long, cylindric, much-branched. Stems simple or sparingly branched, rigid, at the base covered with straw-yellow rigid imbricate perished leaf sheaths and petioles. Basal leaves rosulate, 5-21 cm long, numerous, very dense hairs on both sides; petioles (3-15 cm) longer than or nearly equal to blades; sheaths narrowly long-ovate, lavender; blades linear or narrowly-ovate in outline, 2-3-pinnate, primary pinnae 5-8 pairs; terminal leaf lobes (0.5-2 mm, narrowly ovate to ovate). Low cauline leaves similar to basal leaves but smaller, with narrowly long-ovate sheaths; middle-upper cauline leaves gradually reduced, sessile, with soft ovate sheaths. Compound umbels with 4-10 rays (1-2 cm, sub-equal length), slightly thickened in fruit. Central umbels broader than lateral umbels, up to 3.5 cm in diameter, compact. Bracts 2–5 (minute, 0.4–1.5 mm), oblong, apex obtuse-rounded or cuneate, caducous. Umbellets 0.8-1.8 cm in diameter in fruit, 6–15 flowered; bracteoles 4–6, purplish green, narrowly long-ovate, 2–4 mm; calyx teeth small, narrowly ovate. Petals broadly obovate or narrowly ovate, adaxially whitish-yellow, abaxially purplish-yellow, puberulent on both sides, outer flowers of the umbel radiant with outer petals enlarged, unequally emaginate at the tip, with narrow lobule bent inwards. Stylopods short-conic, wavy at the margin, yellow-green,  $0.3-0.5 \times 0.65-0.9$  mm; styles reflexed, 2-3 mm long. Fruits with slender carpophore, bifurcate to the base; mericarps strongly dorsally compressed, elliptic or broadly elliptic in outline,  $4-7 \times 2-5$  mm, on dorsal surface densely covered by thin hairs. Dorsal ribs filiform and marginal ribs narrowly-winged (0.2-0.5 mm broad). Vittae filiform, 4 on dorsal surface (1/2-3/4 length mericarp), 2 on commissure surface (short, about 1/4 as long as mericarp).

**Fruit anatomy.** Exocarp is formed by one layer of small cells. Outer mesocarp layer is of thin-walled parenchyma cells; inner mesocarp (hypendocarp) is consisted of thick-walled lignified fibrous cells. Five ridges are found on each mericarp. Vascular bundles are thin in dorsal ridges, broad in marginal ridges and commissural side. There are 4 dorsally and 2 ventrally vittae. Endoderm is located as one line under the vittae and seems to be integrated with the spermoderm. The seed is composed of endosperm and spermoderm with a thickened cell wall (Suppl. material 1: Fig. S3).

**Pollen morphology**. The pollen grains are isopolar symmetric, the aperture is tricolporate type. The pollen shape is prolate with an ellipsoidal equatorial outline,



**Figure 4.** Illustrations of *Semenovia gyirongensis* (from the holotype) **A** Habit **B** Basal leaf **C** Compound umbel **D** Flower **E** Dorsal surface of mericarp **F** Commissural surface of mericarp.

the polar ends are rounded and the ornamentation is cerebroid. Polar axis (P) =  $26.53 \pm 0.85 \mu m$ , equatorial axils (E) =  $13.43 \pm 0.9 \mu m$  (n = 20) (Fig. 1O–Q and Fig. 2A6).

**Phenology.** The species was found flowering in July–September, fruiting in August–October.

**Distribution and habitat.** *S. gyirongensis* is only known from the type locality, China, Xizang, Gyirong County, Woma village, near Longda (Suppl. material 1: Fig. S2). It grows on screes, rocky slopes and sandy places, at elevations between 4000 and 4150 m.

**Etymology.** The specific epithet is derived from the type locality, Gyirong County in Xizang, China.

**Conservation status.** *S. gyirongensis* is hitherto known only from Gyirong County (the type locality) where it usually grows on screes, rocky slopes and sandy places, locally common. In field investigation, we found that the area is subjected to overgrazing pressure and only a handful of individuals can escape from eating or trampling, ultimately blossoming and fruiting. Because of its localized distribution and grazing pressure, it should be assessed as "Vulnerable" (VU) according to the IUCN (2016).

Additional specimens examined (paratypes). China: Xizang, Gyirong County, near Longda, 5 July 1975, Z. Y. Wu et al. 75-0676 (barcode: KUN0565801!, PE 00756653!, PE 00756650! and HNWP 53717!).

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## Supplementary material I

### **Supporting Information**

Authors: Qun Ying Xiao, Jin Bo Tan, Hao Yu Hu, Song Dong Zhou, Xing Jin He Data type: species data

- Explanation note: The following Supporting Information is available for this article: Figure S1–S3 and Tables S1–S2.
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**RESEARCH ARTICLE** 



## Differentiating *Iconella* from *Surirella* (Bacillariophyceae): typifying four Ehrenberg names and a preliminary checklist of the African taxa

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#### Abstract

To comply with the new phylogeny within the Surirellales as supported by molecular and morphological data, re-evaluations and re-combinations of taxa from and within the genera *Surirella, Cymatopleura*, and *Stenopterobia* and with the re-established genus *Iconella* are necessary. Since the African diatom flora is rich with taxa from these genera, especially *Iconella*, and the authors have studied these taxa recently, describing also new taxa, a preliminary checklist of African *Iconella* and *Surirella* is here presented. 94 names are contained on this list. 57 taxa have been transferred to *Iconella*; 55 taxa were formerly ranked within *Surirella* and two taxa within *Stenopterobia*. 10 taxa have stayed within *Surirella* and six taxa have been transferred from *Cymatopleura* to *Surirella*. 20 *Surirella* and 1 *Stenopterobia* names are listed which are either unrevised or unrevisable since morphological data is missing. Four names and taxa described by Ehrenberg are here typified. Two had been transferred to *Iconella* already: *Iconella bifrons* (Ehrenb.) Ruck & Nakov and *Iconella splendida* (Ehrenb.) Ruck & Nakov. Two are re-transferred from *Cymatopleura* to *Surirella librile* (Ehrenb.) Ehrenb. and *Surirella undulata* (Ehrenb.) Ehrenb.; both taxa are currently known by their younger synonyms: *Cymatopleura solea* (Bréb.) W. Smith and *Cymatopleura elliptica* (Bréb. ex Kützing) W. Smith. Lectotypes for *Iconella bifrons, I. splendida, Surirella librile*, and *S. undulata* were designated.

#### Keywords

diatoms, Surirellales, types, nomenclatural changes, biodiversity

#### Introduction

*Surirella* taxa have been recognized, drawn, and described very early in diatom history since they often have large cells. The genus *Surirella* Bory is within the first published diatom genera which are still in current use: *Bacillaria* by Gmelin in 1791, *Fragilaria* by Lyngbye in 1819, *Achnanthes* and *Navicula* by Bory in 1822, *Diatoma* by Bory in 1824, *Melosira* and *Meridion* by Agardh 1824, *Surirella* by Turpin in 1828; further important genera were later described such as *Cymbella* by C. Agardh in 1830, *Gomphonema* by Ehrenberg in 1832, *Encyonema* by Kützing in 1833, *Eunotia* by Ehrenberg in 1837, *Achnanthidium* by Kützing in 1844, *Campylodiscus* by Ehrenberg ex Kützing in 1844, *Nitzschia* by Hassall in 1845, etc.

The genus name *Surirella* was introduced by P.J.F. Turpin in 1828 who had found it in a collection by the French medical doctor Suriray from brackish waters at the coast of Le Havre in France. He published beautiful drawings which had been enlarged in the microscope by 300×. Ehrenberg also used this 300x enlargement for his research and used this genus name first in 1834 for *Surirella bifrons* and *Surirella splendida*; in his 1838 publication (Ehrenberg 1838) he ranked *Surirella* as a subgenus of *Navicula* and contained in it the species *librile, splendida, bifrons, undulata, striatula* (type of the name of the genus *Surirella* introduced by Turpin), and *constricta* (no *Surirella* according to Jahn and Kusber 2004). For each of these he added a ? between the genus and the epithet which meant that he thought that this species might belong to a new genus to be differentiated from *Navicula*; at the end of the text he wrote that they definitely belong to the genus *Surirella* because of their different mode of division in comparison to *Navicula*. By 1845 Ehrenberg (1845a, b) had also recombined *Navicula librile* and *Navicula undulata* with *Surirella* (see typifications below).

Subsequently, more Surirella taxa were discovered. W. Smith (1851: 7) explains the morphology of Surirella: "Valves concave, with a longitudinal central line and margins produced beyond the suture (winged). ... The concavity of the valves, their winged margins, and the longitudinal central line, which wants the central depression so conspicuous in the Naviculae, are characters which sufficiently distinguish Surirella from all other genera. I believe a careful examination of the loricae ... would detect the presence of alae in all the species." In this paper he also described and differentiated his new genus Cymatopleura against Surirella, the main differences being "the undulated surface of the valves seems to indicate a peculiarity of structure sufficient to constitute a generic difference, and the absence of alae and costae implies a further diversity in the internal character which cannot be regarded as unimportant" (W. Smith 1851: 12). Subsequently, W. Smith recombined Cymatopleura solea (= S. librile Ehrenb.) and Cymatopleura elliptica (= S. undulata Ehrenb.). In his Treatise on the Diatoms, Van Heurck (1896: 374) reintroduced and validated the genus Stenopterobia which had been first mentioned by Brébisson; his short differential diagnosis against Surirella is: "Frustules very elongated and very narrow, sometimes sigmoid."

All the above mentioned genera, Surirella, Cymatopleura, Stenopterobia, Campylodiscus (for C. clypeus (Ehrenb.) Ehrenb. ex Kütz. see Poulíčková and Jahn 2007) are part of the order Surirellales (sensu Round et al. 1990, Ruck and Kociolek 2004, and Ruck et al. 2016a) which are canal-raphe-bearing diatoms with a circumferential raphe at the entire valve margin. The genera *Epithemia* and *Rhopalodia* which have a canal-raphe-not positioned around the entire valve margin, had been placed into the order Rhopalodiales (Round et al. 1990) but Ruck et al. (2016a) placed them also into the order Surirellales because their monophyly is strongly supported by molecular data (Ruck and Theriot 2011, Ruck et al. 2016a). However, the publications of Ruck et al. (2016a, 2016b), performed with morphology and molecular markers on those Surirellales, strongly reject the monophyly of several genera in the current classification (Round et al. 1990), especially concerning the genera *Surirella* and *Campylodiscus*. In order to provide a home to taxa which do not fit into their strict genus definition, Ruck et al. (2016b) reintroduced the genus *Iconella* which had been established by Jurilij in 1949 and *Coronia* which had been established as a subgenus by Ehrenberg, validated by Grunow and raised to genus rank by Ruck and Guiry (2016).

In the tropical African aquatic ecosystems, taxa from the genera *Surirella* and *Cymatopleura*, as traditionally known, play an important role (Ross 1983, Cocquyt and Vyverman 1994, Cocquyt 2000). In typifying historical material from African waters as described by Otto Müller (Cocquyt and Jahn 2005, 2007a, 2007b, 2007c, 2007d, 2014), by Cholnoky (Cocquyt et al. 2017), by Foged (Cocquyt and Kusber 2010), by Woodhead and Tweed (Cocquyt et al 2013), we have tried to reevaluate earlier findings of these taxa as well as their endemism. In order to help researchers to name their taxa correctly, we are providing a list of African taxa which have been recombined with a different genus; we are also listing those taxa whose names did not change. Since some of Ehrenberg's species have been the basis for varieties of African taxa, we are including the typification of four taxa originally described by Ehrenberg and synonymizing two younger taxa.

#### Material and methods

From the Ehrenberg Collection at BHUPM (Museum für Naturkunde, Berlin), the following materials (for details of the collection see Jahn and Kusber 2004) were investigated:

540128-6 (Iconella bifrons) 540178-1 (Iconella splendida) 540177-3 (Surirella librile) 540177-4 (Surirella librile) 540138-6 (Surirella undulata) Zeichenblatt No 1130 (Iconella bifrons) Zeichenblatt No 1160 (Iconella splendida) Zeichenblatt No 1151 (Surirella librile) Zeichenblatt No 1163 (Surirella undulata) New names and typifications are registered in PhycoBank (Kusber et al. 2017), a registration system for nomenclatural acts (see Barkworth et al. 2016) which is currently in the trial phase. Stable http identifiers are linking to the prototype portal. When possible, we are using long-term stable and semantic web compatible identifiers for specimens according to Güntsch et al. (2017).

Two specimens at BR (Botanic Garden Meise) have been reinvestigated and documented. For specimens not seen at BRM (Alfred-Wegener-Institut für Polar- und Meeresforschung, Hustedt Diatom Study Centre, Bremerhaven), Simonsen (1987) was consulted. Author names are standardized according to IPNI database (The International Plant Names Index 2017). For several nomenclatural details the Index Nominum Algarum (1988+) and the AlgaTerra database (Jahn and Kusber 2005+) have been used.

#### **Results and discussion**

Typification of species described by Ehrenberg

#### Iconella bifrons (Ehrenb.) Ruck & Nakov in Notulae algarum 10: 1. 2016.

- *≡ Navicula bifrons* Ehrenb. in Abh. Königl. Akad. Wiss. Berlin 1833: 259. 1834.
- ≡ Surirella bifrons (Ehrenb.) Ehrenb. in Abh. Königl. Akad. Wiss. Berlin 1841: 388. 1843.

**Lectotype** (designated here). BHUPM 540128-6 "Trockenpräparate CXXVIII 6". (The valve representing the lectotype is reproduced here as Fig. 1A).

http://phycobank.org/100029

**Comments.** The combination in Ehrenberg (1843) has been accepted by Kützing (1844: 61). The specimen of the lectotype was misprinted as "547806-3" in Cocquyt and Jahn (2007b) (McNeill et al. 2012, Art. 7.10). *Iconella bifrons* was introduced in Ruck et al. (2016a) and validated in Ruck et al. (2016b).

#### Iconella splendida (Ehrenb.) Ruck & Nakov in Notulae algarum 10: 2. 2016.

*≡ Navicula splendida* Ehrenb. in Abh. Königl. Akad. Wiss. Berlin 1831: 81. 1832.

*≡ Surirella splendida* (Ehrenb.) Ehrenb. in Abh. Königl. Akad. Wiss. Berlin 1841: 389. 1843.

**Lectotype** (designated here). [icon!] Drawing BHUPM 1160. (The cell representing the lectotype is reproduced here as Fig. 2A "2-4").

http://phycobank.org/100030



**Figure 1.** *Iconella bifrons* **A–B** Lectotype: BHUPM 540128-6 **C–D** Ehrenberg's drawing BHUPM 1130 showing different shapes of the same species in Ehrenberg's concept. Scale bar for  $\mathbf{A} = 10 \ \mu m$ .



**Figure 2.** *Iconella splendida.* Lectotype: Drawing BHUPM 1160. **A** The alive cell representing the lectotype in three views (hand written numbers 2-4), length 188  $\mu$ m **B** Later documentation of valve details by Ehrenberg, hand written numbers 5-6 represent a 226  $\mu$ m long cell.

**Further material.** Mica preparation BHUPM 540178-1 shows a girdle view with dark inclusions and is not informative for identification.

**Comment.** *Iconella splendida* was introduced in Ruck et al. (2016a) and validated in Ruck et al. (2016b).

## *Surirella librile* (Ehrenb.) Ehrenb. in Ber. Bekanntm. Verh. Königl. Preuss. Akad. Wiss. Berlin 1845: 139 table. 1845.

≡ *Navicula librile* Ehrenb. in Abh. Königl. Akad. Wiss. Berlin 1831: 81. 1832.

**Lectotype** (designated here). [icon!] BHUPM 1151c, d. (The cell representing the lectotype is reproduced here as Fig. 3A–B).

http://phycobank.org/100031

**Further material.** BHUPM 540177-3 "Trockenpräparate CLXXVII 3" (Fig. 3D), BHUPM 540177-4" Trockenpräparate CLXXVII 4" (Fig. 3C).

#### Synonyms.

= Cymbella solea Bréb. in Brébisson & Godey, Alg. Falaise: 51, pl. VII, p.p. 1835.

*≡ Surirella solea* (Bréb.) Bréb., Consid. Diat.: 17. 1838.

≡ Cymatopleura solea (Bréb.) W. Sm. in Ann. Mag. Nat. Hist. ser. 2. 7: 12. 1851.

**Nomenclatural comment.** Ehrenberg (1845a) introduced and used the name *Surirella librile*. In this publication (1845a) he described all species new to science formally with a Latin diagnosis. Because he did not mark the species as new to science, Ehrenberg introduced the name *Surirella librile* as a new combination of *Navicula librile* under the then accepted genus name *Surirella*. This combination can be verified



**Figure 3.** *Surirella librile*. Lectotype: Drawing BHUPM 1151. **A** Girdle view representing the lectotype (corresponding to preparation BHUPM 540177-3 in 3D) **B** Valvar view representing the lectotype; Ehrenberg indicated two views of one cell with dots between the undulated girdle view in A and the valvar view in B. **C** Corresponding preparation BHUPM 540177-4 **D** Corresponding preparation BHUPM 540177-3 **E** Documentation of Ehrenberg's observations in 1826 **F** Small cells in girdle view not corresponding to the published protologue. Scale bar for **C–D** = 10 µm.

by the images Ehrenberg (1854) provided e.g. for Berlin material "Brakisches, strichweis lebendes, Erdlager unter Berlin" (Ehrenberg 1854: pl. 14: fig. 38).

Taxonomical comment. Ehrenberg (1832) published Navicula librile by a description which included the length of 1/10 Paris Line which is 225.6 µm. But this measurement does not correspond to the first observations he made in Berlin 1826 drawn on a small piece of paper (Fig. 3E) and glued onto the drawing sheet BHUPM 1151. Nevertheless, the published measurement corresponds perfectly to two of his specimens on his drawing sheet BHUPM 1151 showing a living cell in valvar and girdle view (Fig. 3A–B). Therefore, Ehrenberg (1832) was the first who described the species which was some years later described again as Cymbella solea Bréb. & Godey (1835) which was later recombined as Cymatopleura solea (Bréb.) W. Sm. (1851) and became type of the name of the genus Cymatopleura (Smith 1851). Ehrenberg's specimens, probably deposited in 1835 or 1836 (see Ehrenberg 1838) give proof (Fig. 3C-D) of his earlier findings (Ehrenberg 1832). In addition, Ehrenberg apparently also observed the form which is identified today as "Cymatopleura solea var. apiculata" (cf. Fig. 3F, e.g. Krammer & Lange-Bertalot 1988, Hofmann et al. 2013). Schoeman and Archibald (1979) had accepted Ehrenberg's taxon as having priority under Cymatopleura. Later Cymatopleura was conserved against Sphinctocystis Hassall with Cymatopleura solea as its type (see Wiersema et al. 2015). Since *Cymatopleura* is here not accepted at the rank of a genus, this conservation is not applicable to our taxonomic treatment.

## *Surirella undulata* (Ehrenb.) Ehrenb. in Ber. Bekanntm. Verh. Königl. Preuss. Akad. Wiss. Berlin 1845: 307. 1845.

*≡ Navicula? undulata* Ehrenb., Infusionsthierchen, 187, pl. XXI: fig. XVI. 1838.

**Lectotype** (designated here). BHUPM 540138-6 "Trockenpräparate CXXXVIII 6" (The valve representing the lectotype is reproduced here as Fig. 4D).

http://phycobank.org/100032

Further original material. Drawing BHUPM 1163.

#### Synonyms.

Surirella elliptica Bréb. ex Kütz., Kieselschal. Bacill., 61, pl. 28: fig. 28. 1844.

≡ Cymatopleura elliptica (Bréb. ex Kütz.) W. Sm. in Ann. Mag. Nat. Hist. ser. 2, 7: 13. 1851.

**Comment.** Ehrenberg (1845b) introduced and used the name *Surirella undulata*. In this publication he described all species new to science formally with a Latin diagnosis. Because he did not mark the species as new to science, Ehrenberg introduced the name *Surirella undulata* as a new combination of *Navicula undulata* under the then accepted genus name *Surirella*. This combination can be verified by the drawing Ehrenberg (1854) provided e.g. for Berlin material "Brakisches, strichweis lebendes, Erdlager unter Berlin" (Ehrenberg 1854: pl. 14: fig. 39). Since Ehrenberg published this taxon name already in 1838, his name has priority over *Surirella elliptica*.



**Figure 4.** *Surirella undulata.* **A–C** Drawing BHUPM 1163 **D** Lectotype: BHUPM 540138-6, Trock-enpräparate CXXXVIII 6. Scale bar for **D** = 10  $\mu$ m.

## **Autapomorphies**

In the Surirellaceae the raphe canal runs marginally at the edge of the valve. This canal is interrupted on the external valve face at the poles of the valve while internally the raphe is continuous at the head pole, and interrupted at the base pole. Differences between the three genera had been defined as (according to Hofmann et al 2011):

- *Cymatopleura*: valves are crossed by several large undulations which are not interrupted near the median line (= axial area). The raphe is located within a shallow keel (Spaulding and Edlund 2008).
- *Stenopterobia:* valves are elongated or curved sigmoid-like with equally sized poles. The canal raphe is raised above the valve onto a keel (Spaulding and Edlund 2010).
- *Surirella*: valves are iso- or heteropolar, transapical undulations are finely structured and interrupted near the median line.
  - *Pinnatae* group: raphe canal sits directly at the valve mantle; the raphe is interrupted at both poles. Supporting elements are the fibulae which project from the valve mantle more or less into the center of the valve face.
  - *Robustae*: raphe canal rises above valve face and mantle and is located on a wing. Where the canals of the wings, the alar canals, meet the valve face, in LM appears an apically running wavy line which has been named a loop (Schleifenbildung). Between the alar canals lie fenestrae.

These traditional differentiations based on outline, undulations and median line (formerly named pseudoraphe or axial area) were not supported by the molecular data (Ruck et al. 2016a). Ruck et al. (2016a) therefore proposed morphological autapo-

morphies for the differentiation of genera. As a true autapomorphy they accepted only the morphological differentiation between the *Pinnatae* and the *Robustae* group within *Surirella* which means the raphe canal is located either directly on the mantle (*Pinnatae*) or rises above the valve and mantle and has alar canals with fenestral openings occluded by fenestral bars (*Robustae*).

Since the type of the name of the genus *Surirella*, *S. striatula*, belongs to the *Pinnatae* group, the *Pinnatae* make up the true *Surirella* genus including also the taxa from the *Cymatopleura* genera because their raphe canal also is located on the valve mantle. Taxa from the *Robustae* group as well as *Stenopterobia* taxa – and a few *Campylodiscus* taxa i.e. *C. hibernicus* – belong to the reinstated genus *Iconella*. Since alar canals have also been found in marine *Campylodiscus* sensu lato (now *Coronia* (Ehrenb. ex Kütz.) Ruck & Guiry), an additional autapomorphy for *Iconella* besides the occluded fenestral openings are the internally rimmed pores.

This means that the above list of features for identifying the genera needs to be revised (according to Ruck et al. 2016):

- *Campylodiscus* s.s. (*C. clypeus* only plus formerly *Surirella Fastuosae*; most of its marine taxa are now *Coronia*, the freshwater taxa *Iconella*): communication between the raphe canal and interior through a funnel- or chalice-shaped structure.
- *Coronia* (formerly marine *Campylodiscus*): raphe canal rises above the valve and mantle; it has alar canals with fenestral openings often unoccluded and with simple unrimmed pores.
- *Surirella* s.s. (restricted to the *Surirella Pinnatae* plus *Cymatopleura*): the raphe canal is located directly on the mantle.
- *Iconella* (formerly *Surirella Robustae*, *Stenopterobia* plus formerly *Campylodiscus Robusti*): raphe canal rises above the valve face and mantle and has alar canals with fenestral openings occluded by fenestral bars with internally rimmed pores.

*Campylodiscus* taxa reported from tropical Africa are few. Beside the more common *C. clypeus* and *C. clypeus* var. *bicostata* (W. Sm. ex Roper) Hust. the only endemic species is *Campylodiscus tanganicae* Hust., reported from Lake Tanganyika. Since we cannot determine currently to which genus the African taxa associated historically with *Campylodiscus* belong, we have excluded them from this study. Marine *Coronia* taxa are also not part of this study.

The African *Rhopalodia* and *Epithemia* taxa as described in O. Müllers papers are currently being studied by us and will be published elsewhere.

#### African Iconella Taxa

## Iconella aculeata (Hust.) Cocquyt & R. Jahn, comb. nov.

≡ Surirella aculeata Hust. in Huber-Pestalozzi, Phytoplankt. Süsswass. vol. 2 (2), 503, fig. 609. 1942.

- **Lectotype** (designated by Simonsen 1987). BRM X1/1 Lake Tanganyika "Tanganikasee". http://phycobank.org/100033
  - Surirella aculeata Hust. in A.W.F. Schmidt, Atlas Diatom.-Kunde, pl. 354: fig. 9; pl. 355: fig. 1. 1922, nom. inval.

#### Iconella acuminata (Hust.) Cocquyt & R. Jahn, comb. nov.

≡ Surirella acuminata Hust. in Huber-Pestalozzi, Phytoplankt. Süsswass. vol. 2 (2), 501, fig. 606. 1942.

**Lectotype.** (designated by Simonsen 1987). BRM X1/7 Lake Tanganyika "Tanganyika See. 6".

http://phycobank.org/100034

- Surirella acuminata Hust. in A.W.F. Schmidt, Atlas Diatom.-Kunde, pl. 355: 5 - 6. 1922, nom. inval.

#### Iconella anassae (Cholnoky) Cocquyt & R. Jahn, comb. nov.

≡ Surirella anassae Cholnoky in Oesterr. Bot. Z. 104: 84, fig. 278–279. 1957.

**Lectotype** (designated by Cocquyt et al. 2017). UNWH NIWR 186/3707 "Tugela Village, Nkunzini".

http://phycobank.org/100035

#### Iconella africani-orientalis (Cocquyt & R. Jahn) Cocquyt & R. Jahn, comb. nov.

- *≡ Surirella africani-orientalis* Cocquyt & R. Jahn in Willdenowia 35: 364. 2005.
- ≡ Surirella constricta var. africana O. Müller in Bot. Jahrb. Syst. 34: 32, pl. 2: fig. 1. 1903.
- *≡ Surirella muelleri* Hust. [non Forti] in A.W.F. Schmidt, Atlas Diatom.-Kunde, pl. 355: fig. 2 (caption). 1922, nom. illeg.

**Lectotype** (designated by Cocquyt and Jahn 2005a). [icon] Müller 1903, pl. 2, fig. 1; reproduced as fig. 8 in Cocquyt and Jahn (2005) "Plankton of Lake Malombe [Malawi]".

http://phycobank.org/100036

Surirella constricta var. maxima O. Müll. in Bot. Jahrb. Syst. 34: 32, pl. 2: fig. 2. 1903.

**Lectotype** (designated by Cocquyt and Jahn 2005a). [icon] Müller 1903, pl. 2, fig. 2; reproduced as fig. 7 in Cocquyt and Jahn (2005a) "Plankton of Lake Malawi, northern part, Tanzania".

#### Iconella agonaensis (Foged) Cocquyt & R. Jahn, comb. nov.

*≡ Surirella agonaensis* Foged in Biol. Skr. 15 (1): 123, 151, pl. 25: fig. 3. 1966.

Holotype. C Ghana 141/1961. "Southwest Ghana. Fresh water (a small stream in bamboo thicket between the villages Agona and Nsuaem, Loc. No. 12). 9.III.1961." http://phycobank.org/100037

## *Iconella approximata* (Woodhead & Tweed ex Cocquyt, Jüttner & Kusber) Cocquyt, Jüttner & Kusber, comb. nov.

*≡ Surirella approximata* Woodhead & Tweed ex Cocquyt, Jüttner & Kusber in Diatom Res. 28: 122. 2013.

Holotype. NMW C90.12.179 "River Chigara, Sierra Leone".

http://phycobank.org/100038

- *Surirella approximata* Woodhead & Tweed in Hydrobiologia 12 (2/3): 202, pl. 6 figs 71, 73. 1958, nom. inval.

### Iconella bonsaensis (Foged) Cocquyt & R. Jahn, comb. nov.

≡ Surirella bonsaensis Foged in Biol. Skr. 15 (1): 124, 151, pl. 25: fig. 1. 1966.

Holotype. C Ghana 151/1961. "Southwest Ghana. Fresh water (the Bonsa river, a tributary to the Ankobra river; Loc. No. 14). 9.III.1961." http://phycobank.org/100039

#### Iconella brevicostata (O. Müll.) Cocquyt & R. Jahn, comb. nov.

≡ Surirella brevicostata O. Müll. in Bot. Jahrb. Syst. 34: 34-35, pl. 2, fig. 9. 1903.

Lectotype (designated by Cocquyt and Jahn 2005a). B 40 0040181 [http://herbarium. bgbm.org/object/B400040181] "Lake Malombe after discharge of Lake Nyassa [Lake Malawi, Malawi] (sample B 52 0000039 [http://herbarium.bgbm.org/object/B520000039])".

http://phycobank.org/100040

= Surirella tanganyikae G.S. West in J. Linn. Soc., London. Bot. 38: 166, pl. 8: fig. 6. 1907.

Localities. "Tanganyika – In plankton, Kituta Bay (25 Aug. 1904; no. 77), near Mbete (28 Sept. 1904; no. 105, and near Kala (19 Nov. 1904; no. 170)".

## Iconella brevicostata var. constricta (Hust.) Cocquyt & R. Jahn, comb. nov.

≡ Surirella brevicostata var. constricta Hust. in Huber-Pestalozzi, Phytoplankt. Süsswass. vol. 2 (2), 505, fig. 615. 1942.

Lectotype (designated by Simonsen 1987). BRM 220/39 Lake Tanganvika "Tanganyika - G.S. West, Exp.".

http://phycobank.org/100041

- Surirella brevicostata var. constricta in A.W.F. Schmidt, Atlas Diatom.-Kunde, pl. 309: fig. 2. 1914, nom. inval.

#### Iconella brevicostata var. elongata (Hust. ex Simonsen) Cocquyt & R. Jahn, comb. nov.

- $\equiv$  Surirella brevicostata var. elongata Hust. ex Simonsen, Atlas and Catalogue of the Diatom Types of F. Hustedt 1: 50. 1987.
- Holotype. BRM X1/59 Lake Tanganyika "Tanganyika-See.". http://phycobank.org/100042
  - Surirella brevicostata var. elongata Hust. in A.W.F. Schmidt, Atlas Diatom.-Kunde, pl. 309: fig. 1. 1914, nom. inval.

### Iconella chasei (Cholnoky) Cocquyt & R. Jahn, comb. nov.

*≡ Surirella chasei* Cholnoky in Portugaliae Acta Biol. Sér. B 4: 225, fig. 118–119, 1954.

Lectotype (designated by Cocquyt et al. 2017). UNWH NWU 07-172 "Eastlands, Umtali District, Southern Rhodesia (now Zimbabwe). Stream bank fully exposed to sunlight, source of mountain ravine on a fern hill on border of Eastlands".

http://phycobank.org/100043

#### Iconella cataractarum (Cocquyt & J.C. Taylor) Cocquyt & J.C. Taylor, comb. nov.

 $\equiv$  Stenopterobia cataractarum Cocquyt & J.C. Taylor in Phytotaxa 158: 78, figs 1–38. 2014.

Holotype. BR 4345. "Zambia, Luapula Province, Ntumbachushi Falls, 09.853736° S, 28.944683° E, leg. J.C. Taylor 12-349".

http://phycobank.org/100044

## Iconella chepurnovii (Cocquyt & R. Jahn) Cocquyt & R. Jahn, comb. nov.

*≡ Surirella chepurnovii* Cocquyt & R. Jahn in Nova Hedwigia 84: 542, figs 45–47. 2007.

Holotype (in Cocquyt and Jahn 2007d). BR 4099 (ACBUA 576) Lake Tanganyika "Lacus Tanganyika, Gatororongo (Burundi), Africa centralis".

Isotype (in Cocquyt and Jahn 2007d). B 40 0040243 [http://herbarium.bgbm. org/object/B400040243].

http://phycobank.org/100045

# *Iconella coei* (Cholnoky ex Cocquyt, J.C. Taylor & Kusber) Cocquyt, J.C. Taylor & Kusber, comb. nov.

≡ *Surirella coei* Cholnoky ex Cocquyt, J.C. Taylor & Kusber in Fottea 17(1): 39, figs 30–39. 2017.

Holotype. UNWH NIWR 332/6627 "Mount Kenya".

http://phycobank.org/100046

- Surirella coei Cholnoky in Oesterr. Bot. Z. 107: 362, fig. 25-26, 1960, nom. inval.

## Iconella congolensis (Cocquyt & J.C. Taylor) Cocquyt & J.C. Taylor, comb. nov.

≡ Surirella congolensis Cocquyt & J.C. Taylor in Eur. J. Taxon. 133: 8, figs 6–9. 2015.

Holotype. BR 4399 "Oriental Province, DR Congo, Lomami River (0.49339° N and 24.16960° E). Epiphyton on dead submerged wood". http://phycobank.org/100047

## Iconella crawfordii (Cocquyt & R. Jahn) Cocquyt & R. Jahn, comb. nov.

- ≡ Surirella crawfordii Cocquyt & R. Jahn in Syst. Geogr. Pl. 77: 218, fig. 3C. 2007.
- ≡ Surirella fuellebornii var. tumida Hust. in Huber-Pestalozzi, Phytoplankt. Süsswass. vol. 2 (2), 495, fig. 596. 1942.

**Lectotype** (cited as holotype but in fact designated by Simonsen 1987). BRM X6/63 Lake Tanganyika "Tanganyika See".

http://phycobank.org/100048

- *Surirella fuellebornii* var. *tumida* Hust. in A.W.F. Schmidt, Atlas Diatom.-Kunde, pl. 355: fig. 10. 1922, nom. inval.

#### Iconella debesii (Hust.) Cocquyt & R. Jahn, comb. nov.

*≡ Surirella debesii* Hust. in A.W.F. Schmidt, Atlas Diatom.-Kunde, pl. 356: figs 3, 4. 1922.

**Lectotype** (designated by Simonsen 1987). BRM X7/59 Lake Tanganyika "Tanganikasee" of the plate.

http://phycobank.org/100049

**Comment.** Description in the caption in Hustedt (1922).

#### Iconella delicatissima var. ghanaensis (Foged) Cocquyt & Kusber, comb. nov.

- ≡ Surirella delicatissima var. ghanaensis Foged in Biol. Skr. 15 (1): 124, 151, pl. 25: fig. 9. 1966.
- ≡ Stenopterobia delicatissima var. ghanensis (Foged) Cocquyt & Kusber in Nova Hedwigia 91: 126. 2010.

**Holotype.** C Ghana 204/1961 "West Ghana. Fresh water (a small river north of the village Dwinyana; Loc. No. 30). 12.III.1961."

http://phycobank.org/100050

- Surirella delicatissima var. africana Cholnoky 1959, nom. inval.

**Comment.** Variety of *Iconella delicatissima* Ruck & Nakov in Notulae algarum 10: 3. 2016.

#### Iconella dodowaensis (Foged) Cocquyt & R. Jahn, comb. nov.

*≡ Surirella dodowaensis* Foged in Biol. Skr. 15 (1): 124, 151, pl. 25: fig. 6. 1966.

**Holotype.** C Ghana 151/1961 "Southeast Ghana. Fresh water (a river near the village Dodowa, Loc. No. 62). 1.III.1961".

http://phycobank.org/100051

#### Iconella dumae (Hust.) Cocquyt & R. Jahn, comb. nov.

 $\equiv$  Surirella dumae Hust. in Hedwigia 63: 169. 1921.

**Lectotype** (designated by Simonsen 1987). BRM 222/72 "D.O. Afrika. Regenpfütze im Dumagebiet" German East Africa, rain barrel.

http://phycobank.org/100052

Surirella dumae Hust. in A.W.F. Schmidt, Atlas Diatom.-Kunde, pl. 295: fig. 5,
6. 1913, nom. inval.

#### Iconella ebalensis (Cocquyt & J.C. Taylor) Cocquyt & J.C. Taylor, comb. nov.

Surirella ebalensis Cocquyt & J.C. Taylor in Eur. J. Taxon. 133: 3, figs 1-5. 2015.

**Holotype.** BR 4398 "Oriental Province, DR Congo, Lomami River (0.49339° N and 24.16960° E). Epiphyton on *Nymphaea lotus*; collected by François Darchambeau and Ernest Tambwe on 24 Nov. 2012".

http://phycobank.org/100053

## Iconella effusa (Hust.) Cocquyt & R. Jahn, comb. nov.

*≡ Surirella effusa* Hust. in A.W.F. Schmidt, Atlas Diatom.-Kunde, pl. 357: figs 1, 2. 1925.

**Lectotype** (designated by Simonsen 1987). BRM X2/9 Lake Tanganyika "Tanganika See. 6".

http://phycobank.org/100054

**Comment.** Although Hustedt (in Huber-Pestalozzi 1942) reported this taxon as "nicht selten" it was never observed by other investigators.

#### Iconella engleri (O. Müll.) Cocquyt & R. Jahn, comb. nov.

- *≡ Surirella engleri* O. Müll. in Bot. Jahrb. Syst. 34: 28, pl. 1, fig. 4. 1903.
- ≡ *Surirella nyassae* var. *engleri* (O. Müll.) Ostenf. in Bull. Mus. Comp. Zool. Harvard Coll. 52: 178. 1909.

**Lectotype** (designated by Cocquyt and Jahn 2007a). B 40 0040240 [http://herbarium. bgbm.org/object/B400040240] (the valve representing the lectotype was published as fig. 1 in Cocquyt and Jahn 2007a) "Lake Malombe after discharge of Lake Nyassa (Lake Malawi), Malawi".

http://phycobank.org/100055

= Surirella engleri f. angustior O. Müll. in Bot. Jahrb. Syst. 34: 28, pl. 1: fig. 5. 1903.

**Lectotype** (designated by Cocquyt and Jahn 2007a). slide B 40 0040241 [http:// herbarium.bgbm.org/object/B400040241] (the valve representing the lectotype was published as fig. 2 in Cocquyt and Jahn 2007a) "Lake Malombe after discharge of Lake Nyassa (Lake Malawi), Malawi".

= Surirella engleri f. subconstricta O. Müll. in Bot. Jahrb. Syst. 34: 28-29, pl. 1, fig. 6. 1903.

Lectotype (designated by Cocquyt and Jahn 2007a). B 40 0040239 [http://herbarium.bgbm.org/object/B400040239] "Lake Malombe after discharge of Lake Nyassa (Lake Malawi), Malawi".

 Surirella engleri var. constricta O. Müll. in Bot. Jahrb. Syst. 34: 29, pl. 1, figs 7, 8. 1903. Lectotype (designated by Cocquyt and Jahn 2007a). B 40 0040238 [http://herbarium.bgbm.org/object/B400040238] (the valve representing the lectotype was published as fig. 4 in Cocquyt and Jahn 2007a) "Lake Malombe after discharge of Lake Nyassa (Lake Malawi), Malawi".

*= Surirella engleri* [var. *constricta*] f. *minor* Woodhead & Tweed ex Cocquyt, Jüttner & Kusber in Diatom Res. 28:124, fig. 3. 2013.

Holotype. NMW C90.12.229 "Rokupr, site E, Sierra".

= Surirella engleri [var. constricta] f. sublaevis O. Müll. in Bot. Jahrb. Syst. 34: 29, pl. I, fig. 9. 1903.

Lectotype (designated by Cocquyt and Jahn 2007a). B 40 0040238 [http://herbarium.bgbm.org/object/B400040238] (the valve representing the lectotype was published as fig. 5 in Cocquyt and Jahn 2007a) "Lake Malombe after discharge of Lake Nyassa (Lake Malawi), Malawi".

## Iconella esamangensis (Foged) Cocquyt & R. Jahn, comb. nov.

*≡ Surirella esamangensis* Foged in Biol. Skr. 15 (1): 125, 151, pl. 25: fig. 2. 1966.

Holotype. C Ghana 144/1961 "Southwest Ghana. Fresh water (a small river in the rain forest near the village Esamang, Loc. No. 12). 9.III.1961".

http://phycobank.org/100056

#### Iconella friedelhinziae (Cocquyt & R. Jahn) Cocquyt & R. Jahn, comb. nov.

*≡ Surirella friedelhinziae* Cocquyt & R. Jahn in Syst. Geogr. Pl. 77: 218. 2007.

*≡ Surirella fuellebornii* var. *elliptica* O. Müll. In Bot. Jahrb. Syst. 34: 31, pl. 1: fig. 13. 1903.

**Lectotype** (designated in Cocquyt and Jahn 2007b). [icon] Müller 1903, pl. 1, fig. 13 "Lake Tanganyika". 1D in Cocquyt & Jahn (2007).

**Epitype** (designated in Cocquyt and Jahn 2007b). BR 4101 "Lake Tanganyika, Burundi; near Kibwe 105 km south of Bujumbura, sandy, stony beach with abundant tufts of *Vossia cuspidata* Griff. (Poaceae)".

**Isoepitype** (designated in Cocquyt and Jahn 2007b). B 40 0040242 [http://her-barium.bgbm.org/object/B400040242] (ACBUA 660/2).

http://phycobank.org/100057

#### Iconella fuellebornii (O. Müll.) Cocquyt & R. Jahn, comb. nov.

*≡ Surirella fuellebornii* O. Müll. in Bot. Jahrb. Syst. 34: 30. 1903.

Lectotype (designated in Cocquyt and Jahn 2007b). B 40 0040236 [http://herbarium.bgbm.org/object/B400040236] "Lake Malombe".

http://phycobank.org/100058

= Surirella fuellebornii var. constricta O. Müll. Bot. Jahrb. Syst. 34: 30-31, pl. 1, fig. 12.1903.

**Lectotype** (designated in Cocquyt and Jahn 2007b). [icon] Müller 1903, pl. 1, fig. 12. "Lake Malombe" according to Cocquyt and Jahn (2007b).

= Surirella fuellebornii f. subconstricta O. Müll. Bot. Jahrb. Syst. 34: 30, pl. 1, fig. 11 1903.

## Iconella gradifera (Hust.) Cocquyt & R. Jahn, comb. nov.

- *≡ Surirella gradifera* Hust. in Huber-Pestalozzi, Phytoplankt. Süsswass. vol. 2 (2), 501, fig. 605. 1942.
- Lectotype (designated by Simonsen 1987). X2/57 Lake Tanganyika "Tanganikasee. 6". http://phycobank.org/100059
  - Surirella gradifera Hust. in A.W.F. Schmidt, Atlas Diatom.-Kunde, pl. 353: fig. 8, 9. 1922, nom. inval.

## Iconella heidenii (Hust.) Cocquyt & R. Jahn, comb. nov.

≡ *Surirella heidenii* Hust. in A.W.F. Schmidt, Atlas Diatom.-Kunde, pl. 355: fig. 2–4. 1922.

**Lectotype** (designated by Simonsen 1987). BRM X2/58 Lake Tanganyika "Tanganyika See".

http://phycobank.org/100060

## Iconella kusberi (Cocquyt & R. Jahn) Cocquyt & R. Jahn, comb. nov.

≡ Surirella kusberi Cocquyt & R. Jahn in Syst. Geogr. Pl. 77: 221. 2007.

*≡ Surirella bifrons* var. *intermedia* O. Müll. in Bot. Jahrb. Syst. 34: 27, pl. 1: fig. 1. 1903.

**Lectotype** (designated by Cocquyt and Jahn 2007b). [icon] Pl. 1. fig. 1 in Müller (1903) reproduced as fig. 1A in Cocquyt and Jahn (2007b) "unknown" locality.

**Epitype** (designated by Cocquyt and Jahn 2007b). Slide B 40 0040235 [http:// herbarium.bgbm.org/object/B400040235], from Müller's material B 52 0000058 [http://herbarium.bgbm.org/object/B520000058] (the valve representing the epitype in Cocquyt and Jahn 2007b as fig. 7C "The River Olunga (Tanzania)".

http://phycobank.org/100061

#### Iconella lancettula (Hust.) Cocquyt & R. Jahn, comb. nov.

≡ Surirella lancettula Hust. in Huber-Pestalozzi, Phytoplankt. Süsswass. vol. 2 (2), 505, fig. 613. 1942.

**Lectotype** (cited as holotype but in fact designated by Simonsen 1987). BRM X7/58 Lake Tanganyika "Tanganikasee".

http://phycobank.org/100062

- *Surirella lancettula* Hust. in A.W.F. Schmidt, Atlas Diatom.-Kunde, pl. 354: figs 1, 2. 1922, nom. inval.

#### Iconella latecostata (Hust.) Cocquyt & R. Jahn, comb. nov.

- ≡ Surirella latecostata Hust. in A.W.F. Schmidt, Atlas Diatom.-Kunde, pl. 353: figs 5–7. 1922.
- Lectotype (designated by Simonsen 1987). BRM X2/70 Lake Tanganyika "Tanganyika See." http://phycobank.org/100063

#### Iconella likomensis (Cocquyt & R. Jahn) Cocquyt & R. Jahn, comb. nov.

- *≡ Surirella likomensis* Cocquyt & R. Jahn in Willdenowia 35: 361. 2005.
- *≡ Surirella bifrons* [var. *tumida*] f. *minor* O. Müll. in Bot. Jahrb. Syst. 34: 28, pl. 1, fig. 3. 1903.

**Lectotype** (designated by Cocquyt and Jahn 2005a). [icon] Müller 1903: t. 1, fig. 3; reproduced as Fig. 4 in Cocquyt and Jahn (2005) Lake Nyassa [Lake Malawi] near Likoma on the bottom.

**Epitype** (designated by Cocquyt and Jahn 2005a). B 40 0040180 [http://herbarium.bgbm.org/object/B400040180] Lake Malombe after discharge of Lake Malawi, Malawi (sample B 52 0000039 [http://herbarium.bgbm.org/object/B520000039].

http://phycobank.org/100064

**Taxonomical remark.** According to Cocquyt and Jahn (2005a), the taxonomic concept *Surirella biseriata* var. *bifrons* (Ehrenb.) Hust. sec. Hustedt in Schmidt (1912) pro parte falls into synonymy.

#### Iconella linearis var. elliptica (O. Müll.) Cocquyt & R. Jahn, comb. nov.

*≡ Surirella linearis* var. *elliptica* O. Müll. in Bot. Jahrb. Syst. 34: 30, pl. 1: fig.10. 1903.

Lectotype (designated by Cocquyt and Jahn 2005a). B 40 0040182 [http://herbarium.bgbm.org/object/B400040182] Lake Malombe after discharge of Lake Malawi, Malawi (sample B 52 0000039 [http://herbarium.bgbm.org/object/B520000039]).

http://phycobank.org/100065

**Comment.** Variety of *Iconella linearis* (W. Sm.) Ruck & Nakov in Notulae algarum 10: 2. 2016.

#### Iconella linearis var. elongata (Compère) Cocquyt & R. Jahn, comb. nov. et stat. nov.

Surirella linearis f. elongata Compère in Bull. Jard. Bot. Nat. Belg. 45: 380, figs 11, 23. 1975.

Holotype. BR 982 "Chad, Lake Chad". http://phycobank.org/100066

### Iconella malombae (O. Müll.) Cocquyt & R. Jahn, comb. nov.

- *≡ Surirella malombae* O. Müll. in Bot. Jahrb. Syst. 34: 34, pl. 2: figs 5–6. 1903.
- ≡ Surirella nyassae var. malombae (O. Müll.) Ostenf. in Bull. Mus. Comp. Zool. Harvard Coll. 52: 178. 1909.

Lectotype (designated by Cocquyt and Jahn 2007d). B 40 0040230 [http://herbarium.bgbm.org/object/B400040230] "Lake Malombe after discharge of Lake Nyasa (Lake Malawi), Malawi" (sample B 52 0000039 [http://herbarium.bgbm.org/object/ B520000039])".

*Surirella malombae* f. *acuta* O. Müll. in Bot. Jahrb. Syst. 34: 34, pl. 2, fig. 7. 1903.
Lectotype (designated by Cocquyt and Jahn 2007d). [icon] Pl. 2: fig. 7 in Müller (1903) "Lake Malombe, after discharge of Lake Malawi, Malawi".

**Epitype** (designated by Cocquyt and Jahn 2007d). B 40 0040231 [http://herbarium.bgbm.org/object/B400040231] "Lake Victoria near the isle of Djuma" (sample B 52 0000100 [http://herbarium.bgbm.org/object/B520000100]).

http://phycobank.org/100067

= Surirella malombae var. tumida Ostenf. in Bot. Jahrb. Syst. 41: 343. 1908.

#### Iconella margaritifera (Hust.) Cocquyt & R. Jahn, comb. nov.

≡ Surirella margaritifera Hust. in Huber-Pestalozzi, Phytoplankt. Süsswass. vol. 2 (2), 501, fig. 607. 1942.

**Lectotype** (designated by Simonsen 1987). BRM X2/85 Lake Tanganyika "Tanganyika See. 6".

http://phycobank.org/100068

- Surirella margaritifera Hust. in A.W.F. Schmidt, Atlas Diatom.-Kunde, pl. 354: figs 3–5. 1922, nom. inval.

#### Iconella margaritacea (O. Müll.) Cocquyt & R. Jahn, comb. nov.

≡ Surirella margaritacea O. Müll. in Bot. Jahrb. Syst. 34: 37, pl. 2: fig. 12. 1903.

Lectotype (designated by Cocquyt and Jahn 2005a). slide B 40 0040183 [http:// herbarium.bgbm.org/object/B400040183], river Songwe [Tanzania] (sample B 52 0000036 [http://herbarium.bgbm.org/object/B520000036]).

http://phycobank.org/100069

#### Iconella muelleri (Forti) Cocquyt & R. Jahn, comb. nov.

- ≡ Surirella muelleri Forti in Atti R. Ist. Veneto Sc. Lett. Ed Arti 69(2): 1284, 1294, pl. 3: fig. 9, 10. 1910.
- Type locality. Ethiopia, lago Zulay. Coll. Giov. Negri. http://phycobank.org/100070

#### Iconella murielae (Compère) Cocquyt & R. Jahn, comb. nov.

*≡ Surirella murielae* Compère in Bull. Jard. Bot. Nat. Belg. 45: 381, figs 12, 26. 1975.

Holotype. BR 984, Compère 3875. "Lac Tchad, à 10 km au N du delta du Chari, plancton".

http://phycobank.org/100071

**Comment.** This species is illustrated by LM and SEM in Bogaerts et al. (2014), additional illustrations are given here in Fig. 5.

#### Iconella nagbogensis (Foged) Cocquyt & R. Jahn, comb. nov.

*≡ Surirella nagbogensis* Foged in Biol. Skr. 15 (1): 125, 151, pl. 25: fig. 7. 1966.

Holotype. C Ghana 279/1961 "Northeast Ghana. Fresh water (a small river near the village Nagbog, Loc. No. 53). 21.III.1961". http://phycobank.org/100072

#### Iconella nervosa (A.W.F. Schmidt) Cocquyt & R. Jahn, comb. nov.

- *≡ Surirella tenera* var. *nervosa* A.W.F. Schmidt, Atlas Diatom.-Kunde, pl. 23: fig. 15. 1875.
- ≡ Surirella nervosa (A.W.F. Schmidt) Ant. Mayer in Ber. Naturwiss. Vereins Regensburg 14: 341. 1913.

Lectotype (here designated). [icon!] A.W.F. Schmidt, Atlas Diatom.-Kunde, pl. 23: fig. 15. "Whatabevot"

http://phycobank.org/100073

**Taxonomical comment.** From two different localities A.W.F. Schmidt (1875) depicted three valves with an axial area including a central line and spines at both ends of this line. The valve depicted as pl. 23: fig. 15 fits the criterium "illustration with analyses" (McNeill et al. 2012, Art. 38.10) because many small spinules on the valve surface are clearly shown. Therefore we have choosen pl. 23: fig. 15 as the lectotype. fig. 16 is less detailed. We exclude the depicted specimen collected at Khayenmatay (fig. 17) from the species because with its denser costae and less distinct wing projection it probably belongs to a different species.

#### Iconella nyassae (O. Müll.) Cocquyt & R. Jahn, comb. nov.

≡ Surirella nyassae O. Müll. in Bot. Jahrb. Syst. 34: 33, pl. 2: fig. 3. 1903.

Lectotype (designated by Cocquyt and Jahn 2007d). B 40 0040228 "Lake Malawi near Langenburg, Tanzania, between 40-70 m depth (sample B 52 000014 [http://herbarium.bgbm.org/object/B520000014]).

http://phycobank.org/100074

= Surirella nyassae var. sagitta O. Müll. in Bot. Jahrb. Syst. 34: 33, pl. 2: fig. 4. 1903.

Lectotype (designated by Cocquyt and Jahn 2007d). B 40 0040229 "Lake Malawi near Langenburg, Tanzania, between 40-70 m depth" (sample B 52 000013 [http://herbarium.bgbm.org/object/B520000013]).

#### Iconella obtusiuscula (G.S. West) Cocquyt & R. Jahn, comb. nov.

≡ Surirella obtusiuscula G.S. West in J. Linn. Soc., London Bot. 38: 165, pl. 8: fig. 7. 1907.

**Comment.** Type specimen not studied but specimens from Lake Tanganyika observed (Cocquyt 1998).

Localities. "Tanganyika – In plankton, Komba Bay (11 Oct. 1904; no. 135) and near Kala (19 Nov. 1904; no. 170)."

http://phycobank.org/100075



**Figure 5.** *Iconella murielae.* Valve from the holotype slide BR 984. **A**, **C** Overview of the entire valve at different foci **B**, **D** Detail of the middle part of the valve at different foci **B** is showing the fenestral openings below the raphe canal and **D** the striae and the transapical undulations. Scale bar for **A**, **C** = 20  $\mu$ m; scale bar for **B**, **D** = 10  $\mu$ m.

## Iconella oliffii (Cholnoky) Cocquyt & R. Jahn, comb. nov.

≡ Surirella oliffii Cholnoky in Oesterr. Bot. Z. 103: 90, fig. 134, 1956.

**Lectotype** (designated by Cocquyt et al. 2017). [icon]. fig. 134 in Cholnoky (1956) "Umgeni river by Albert Falls. 14.X.1954", leg. W.D. Oliff.

**Epitype** (designated by Cocquyt et al. 2017). UNWH NIWR 193/3860 "Kwa–Zulu Natal, Umgeni River at Albert Falls, Umgeni, South Africa".

http://phycobank.org/100076

#### Iconella panganiensis (O. Müll.) Cocquyt & R. Jahn, comb. nov.

≡ Surirella panganiensis O. Müll. in Bot. Jahrb. Syst. 34: 257-258, figs 3–4. 1904.

**Lectotype** (designated by Cocquyt and Jahn 2005). [icon] Müller 1904, fig. 3; reproduced as fig. 22 in Cocquyt and Jahn (2005a), Rufidji (Usambara-Usagara region) Pangani rapids.

http://phycobank.org/100077

#### Iconella plana (G.S. West) Cocquyt & R. Jahn, comb. nov.

≡ Surirella plana G.S. West in J. Linn. Soc., London Bot. 38: 165, pl. 8: fig. 5. 1907.

Locality. "Tanganyika – In plankton, near Ndauvie (7 Feb. 1905; no. 227)." http://phycobank.org/100078

**Comment.** Type specimen not studied but specimens from Lake Tanganyika observed (Cocquyt 1998).

#### Iconella propinqua (Hust.) Cocquyt & R. Jahn, comb. nov.

- ≡ Surirella propinqua Hust. in Exploration du Parc National Albert, Mission H. Damas 8: 153, pl. 14: fig. 5, 6. 1949.
- Lectotype (designated by Simonsen 1987), BRM 242/6 DR Congo "Belg. Kongo. 39". http://phycobank.org/100079

### Iconella pseudothienemannii (Cholnoky) Cocquyt & R. Jahn, comb. nov.

*≡ Surirella pseudothienemannii* Cholnoky in Beih. Nova Hedwigia 21: 72–73, fig. 184, 185, 1966.

Holotype. UNWH NIWR 169/336 "Uferwasser des Kunene-Flusses bei Swart Boois Drift. Stille Bucht am Südufer, 8.8.1961". http://phycobank.org/100080

## Iconella reicheltii (Hust.) Cocquyt & R. Jahn, comb. nov.

≡ Surirella reicheltii Hust. in Huber-Pestalozzi, Phytoplankt. Süsswass. vol. 2 (2), 501, fig. 607. 1942.

**Lectotype** (designated by Simonsen 1987). BRM X3/69 Lake Tanganyika "Tanganyika See".

http://phycobank.org/100081

- Surirella reicheltii Hust. in A.W.F. Schmidt, Atlas Diatom.-Kunde, pl. 354: figs 3–5. 1922, nom. inval.

#### Iconella sorriensis (Foged) Cocquyt & R. Jahn, comb. nov.

≡ Surirella sorriensis Foged in Biol. Skr. 15 (1): 125, 152, pl. 25: fig. 8. 1966.

Holotype. C Ghana 223/1961 "North Ghana. Fresh water (the Sorri river, the White Volta river system, Loc. No. 35). 16.III.1961". http://phycobank.org/100082

#### Iconella spiraloides (Hust.) Cocquyt & R. Jahn, comb. nov.

≡ Surirella spiraloides Hust. in Huber-Pestalozzi, Phytoplankt. Süsswass. vol. 2 (2), 507, fig. 617. 1942.

**Lectotype** (designated by Simonsen 1987). BRM X4/45 Lake Tanganyika "Tanganika See. 6".

http://phycobank.org/100083

- *Surirella spiraloides* Hust. in A.W.F. Schmidt, Atlas Diatom.-Kunde, pl. 353: fig. 2, 3. 1922, nom. inval.

#### Iconella subcontorta (Hust.) Cocquyt & R. Jahn, comb. nov.

≡ Surirella subcontorta Hust. in Huber-Pestalozzi, Phytoplankt. Süsswass. vol. 2 (2), 518, fig. 633. 1942.

**Lectotype** (designated by Simonsen 1987). BRM X4/57 Lake Tanganyika "Tanganyika See".

http://phycobank.org/100084

- Surirella subcontorta Hust. in A.W.F. Schmidt, Atlas Diatom.-Kunde, pl. 356: fig. 1, 2. 1922, nom. inval.

#### Iconella takoradiensis (Foged) Cocquyt & R. Jahn, comb. nov.

*≡ Surirella takoradiensis* Foged in Biol. Skr. 15 (1): 126, 152, pl. 25: fig. 4. 1966.

**Holotype.** C Ghana 119/1961 "Southest Ghana. Fresh water (a small river in the rain forest west of Takoradi; Loc. No. 8) 8.III.1961".

http://phycobank.org/100085

= Surirella takoradiensis var. suhinensis Foged in Biol. Skr. 15 (1): 126, 152, pl. 25: fig. 5.

Holotype. C Ghana 218/1961 "West Ghana. Fresh water (the Suhin river, the Black Volta river system; Loc. No. 33. 13.III.1961".

#### Iconella tchadensis (Compère) Cocquyt & R. Jahn, comb. nov.

*≡ Surirella tchadensis* Compère in Bull. Jard. Bot. Nat. Belg. 45: 380, figs 11, 23. 1975.

Holotype. BR 987 (see also Bogaerts et al. 2014), Compère 3880, Tchad. Valves from the holotype slide are given in Fig. 6 http://phycobank.org/100086

#### Iconella tumida (O. Müll.) Cocquyt & R. Jahn, comb. nov.

*≡ Surirella bifrons* var. *tumida* O. Müll. in Bot. Jahrb. Syst. 34: 27, t. 1, fig. 2. 1903.

*≡ Surirella tumida* (O. Müll.) Cocquyt & R. Jahn in Willdenowia 35: 361. 2005.

**Lectotype** (designated by Cocquyt and Jahn 2005). [icon] Müller 1903: t. 1, fig. 2; reproduced as fig. 1 in Cocquyt and Jahn (2005a) "Lake Malombe after discharge of Lake Nyassa [Lake Malawi, Malawi]".

**Epitype** (designated by Cocquyt and Jahn 2005a). B 40 0040179 [http://herbarium.bgbm.org/object/B400040179] "Lake Malombe after discharge of Lake Malawi, Malawi (sample B 52 0000038 [http://herbarium.bgbm.org/object/B520000038])".

http://phycobank.org/100087

**Taxonomical remark.** According to Cocquyt and Jahn (2005a), the taxonomic concept *Surirella biseriata* var. *bifrons* (Ehrenb.) Hust. sec. Hustedt (in Schmidt 1911) pro parte falls into synonymy.

#### Iconella turbo (O. Müll.) Cocquyt & R. Jahn, comb. nov.

*≡ Surirella turbo* O. Müll. in Bot. Jahrb. Syst. 34: 34, pl. 2, fig. 8. 1903.

**Lectotype** (designated by Cocquyt and Jahn 2005a). [icon] Müller 1903, pl. 2, fig. 8; reproduced as fig. 24 in Cocquyt and Jahn (2005a) "Lake Malawi, near Island of Likoma (sample B 52 0000025 [http://herbarium.bgbm.org/object/B520000025])".

http://phycobank.org/100088

#### Iconella vasta (Hust.) Cocquyt & R. Jahn, comb. nov.

*≡ Surirella vasta* Hust. in Huber-Pestalozzi, Phytoplankt. Süsswass. vol. 2 (2), 503, fig. 611. 1942.

**Lectotype** (designated by Simonsen 1987). BRM X4/89 Lake Tanganyika "Tanganyika See. 6".

http://phycobank.org/100089

- Surirella vasta Hust. in A.W.F. Schmidt, Atlas Diatom.-Kunde, pl. 354: fig. 6, 7. 1922, nom. inval.

#### Iconella vasta var. linearis (Hust.) Cocquyt & R. Jahn, comb. nov.

*≡ Surirella vasta* var. *linearis* Hust. in Huber-Pestalozzi, Phytoplankt. Süsswass. vol. 2 (2), 504. 1942.

**Lectotype** (cited as holotype but in fact designated by Simonsen 1987). X4/9589 Lake Tanganyika "Tanganyika See. 6".

http://phycobank.org/100090

#### Updated taxonomy of African Surirella taxa

### Surirella afrocalcarata Cocquyt & R. Jahn, nom. nov.

≡ Cymatopleura calcarata Hust. in Huber-Pestalozzi, Phytoplankt. Süsswass. vol. 2 (2), 480, fig. 579. 1942.

Lectotype (designated by Simonsen 1987). BRM Xa/20 Lake Tanganyika "Tanganika See". http://phycobank.org/100091

- Cymatopleura calcarata Hust. in A.W.F. Schmidt, Atlas Diatom.-Kunde, pl. 367: figs 1–2. 1927, nom. inval.

**Comment.** The epithet name "afrocalcarata" was chosen because of *Suriraya calcarata* Pfitzer in Bot. Abh. Morphol. Physiol. 2: 107. 1871. *Suriraya* is a homotypic synonym of *Surirella* Turpin.

#### Surirella clavata (O. Müll.) Cocquyt & R. Jahn, comb. nov.

- ≡ Cymatopleura solea var. clavata O. Müll. in Bot. Jahrb. Syst. 34: 22, fig. 1. 1904.
- *≡ Cymatopleura clavata* (O. Müll.) Cocquyt & R. Jahn in Pl. Ecol. Evol. 147 (3): 413 2014.

**Lectotype** (designated by Cocquyt and Jahn 2014). B 40 0040250 [http://herbarium. bgbm.org/object/B400040250] (the valve representing the lectotype was published as fig. 1D in Cocquyt and Jahn (2014) "Malawi, Lake Malombe, after the discharge of Lake Malawi".

http://phycobank.org/100092



**Figure 6.** *Iconella tchadensis.* **A–D** Valves from the holotype slide BR 987 **A–C** valvar views showing the size range **D** girdle view. Scale bar = 10  $\mu$ m.

## Surirella comperei (Cocquyt & R. Jahn) Cocquyt & R. Jahn, comb. nov.

*≡ Cymatopleura comperei* Cocquyt & R. Jahn in Pl. Ecol. Evol. 147 (3): 419, figs 6–8. 2014.

**Holotype.** B 40 0040184 [http://herbarium.bgbm.org/object/B400040184]; the valve representing the holotype was published as fig. 6E in Cocquyt and Jahn (2014) "Malawi, Lake Malawi near Langenburg".

http://phycobank.org/100093

- Cymatopleura solea var. subconstricta O. Müll. in Bot. Jahrb. Syst. 34: 23. 1904, nom. inval.

- Cymatopleura solea var. [subconstricta] f. major O. Müll. in Bot. Jahrb. Syst. 34: 23. 1904, nom. inval.

- Cymatopleura solea var. [subconstricta] f. minor O. Müll. in Bot. Jahrb. Syst. 34: 23. 1904, nom. inval.

- Cymatopleura solea var. [subconstricta] f. minor O. Müll. in A.W.F.Schmidt, Atlas Diatom.-Kunde, pl. 245: fig. 3. 1904, nom. inval.

## *Surirella distinguenda* Hust. in A.W.F. Schmidt, Atlas Diatom.-Kunde, pl. 283: fig. 5. 1912.

**Lectotype** (cited as holotype but in fact designated by Simonsen 1987). BRM 218/56. "Togo, Westafrika 1912, Lagunenschlick".

#### Surirella fasiculata O. Müll. in Bot. Jahrb. Syst. 34: 36, pl. 1: fig. 14. 1903.

**Lectotype** (designated by Cocquyt and Jahn 2007c). [icon] Müller (1903): pl. 1: fig. 14 "Lake Nogzi, a brackish water lake in the crater of the mountain Nogzi on the northern edge of Kondeland, at 2000 m asl, Tanzania".

**Epitype** (designated by Cocquyt and Jahn 2007c). B 40 0040234 [http://herbarium.bgbm.org/object/B400040234] (the valve representing the epitype was illustrated as fig. 4 in Cocquyt and Jahn 2007c) "basin near the hot spring of Utengule, Beya Mountain (Tanzania)".

## Surirella laticeps (O. Müll.) Cocquyt & R. Jahn, comb. nov.

- *≡ Cymatopleura solea* var. *laticeps* O. Müll. in Bot. Jahrb. Syst. 34: 22-23, fig. 2. 1904.
- *≡ Cymatopleura laticeps* (O. Müll.) Cocquyt & R. Jahn in Pl. Ecol. Evol. 147 (3): 418. 2014.

Lectotype (designated in Cocquyt and Jahn 2014). B 40 0040251 [http://herbarium. bgbm.org/object/B400040251] (the valve representing the lectotype was published as fig. 5 B in Cocquyt and Jahn (2014) "'Nyassaland', Tanzania, Lake Malawi near Langenburg".

http://phycobank.org/100094

## *Surirella modesta* Hust. in A.W.F. Schmidt, Atlas Diatom.-Kunde, pl. 357: fig. 8, 9. 1925.

Lectotype (designated by Simonsen 1987). BRM X2/87 Cameroon "Kamerun, Lagune".

#### Surirella nyansae (G.S. West) Cocquyt & R. Jahn, comb. nov.

≡ Cymatopleura nyansae G.S. West in J. Linn. Soc. Bot. 38: 167, pl. 8: fig. 8. 1907.

Lectotype (designated in Cocquyt and Jahn 2014). BM 34183 "Tanganyika – In plankton, near Kala (19 Nov. 1904; no. 170)."

http://phycobank.org/100095

## Surirella olungensis Cocquyt & R. Jahn in Cryptog. Algol. 28: 111, figs 7–12, 18–21. 2007.

**Holotype.** B 40 0040232 [http://herbarium.bgbm.org/object/B400040232] (the valve representing the holotype is illustrated as fig. 7 in Cocquyt and Jahn 2007c)

"Olunga River (Ohmga) in Ussangu northern Mount Kinga, Tanzania (sample B 52 0000058 [http://herbarium.bgbm.org/object/B520000058])".

#### Surirella ostentata Cholnoky in Hydrobiologia 19: 106, 1962.

*≡ Surirella ovata* var. *africana* Cholnoky in Ber. Deutsch. Bot. Ges. 68: 21–22, fig. 46. 1955.

**Lectotype** (designated by Cocquyt et al. 2017). UNWH NIWR 191/3802 "Bewässerungskanal bei Vredendal near Olifantsriver", leg. A.H.P. Engelbrecht.

http://phycobank.org/100096

#### Surirella ovalis var. apiculata O. Müll. in Bot. Jahrb. Syst. 34: 36, pl. 2: fig. 10. 1903.

**Lectotype** (designated by Cocquyt and Jahn 2007c). [icon] Müller (1903): pl. 2: fig. 10 "basin near the hot spring at Utengule, Tanzania".

= *Surirella ovalis* [var. *apiculata*] f. *minor* O. Müll. in Bot. Jahrb. Syst. 34: 36, pl. 2: fig. 11. 1903.

**Lectotype** (designated by Cocquyt and Jahn 2007c). [icon] Müller (1903): pl. 2: fig. 11 "Lake Rukwa".

#### Surirella pseudotenuis Cholnoky in Portugaliae Acta Biol. Sér. B. 4: 226, fig. 120, 1954.

**Lectotype** (designated by Cocquyt et al. 2017). UNWH NWU 07–138 "Moss growing on rocks at edge of stram in full sunshine in gully South of road to Vumba, Umtali -27.7.1952" leg. N.C. Chase.

http://phycobank.org/100097

#### Surirella rudis Hust. in Arch. Hydrobiol. Suppl. 15: 505. 1938.

**Lectotype** (cited as holotype but in fact designated by Simonsen 1987). BRM X4/3 Lake Tanganyika "Tanganyika See".

- Surirella rudis Hust. in A.W.F. Schmidt, Atlas Diatom.-Kunde, pl. 356: fig. 5, 6. 1922, nom. inval.

## *Surirella sparsipunctata* Hust. in Huber-Pestalozzi, Phytoplankt. Süsswass. vol. 2 (2): 516, fig. 631. 1942.

**Lectotype** (cited as holotype but designated by Simonsen 1987). BRM X4/30 Lake Tanganyika "Tanganikasee. 3rd Tang. Exp., G.S. West".

- *Surirella sparsipunctata* Hust. in A.W.F. Schmidt, Atlas Diatom.-Kunde, pl. 309: fig. 15. 1914, nom. inval.
- = Surirella sparsipuncata var. laevis Hust. in Huber-Pestalozzi, Phytoplankt. Süsswass. vol. 2 (2), 517, fig. 631A. 1942.

**Lectotype** (designated by Simonsen 1987). BRM X4/34 Lake Tanganyika "Tanganikasee 6".

**Comment.** For taxonomical results and discussion see Cocquyt and Vyverman (1993).

#### Surirella striolata Hust. in Arch. Hydrobiol. 18: 249. 1927.

Lectotype (designated by Simonsen 1987). BRM 224/92 Lake Tanganyika "Tanganyika See. Grund. 6, 2".

- Surirella striolata Hust. in A.W.F. Schmidt, Atlas Diatom.-Kunde, pl. 356: fig. 7. 1922, nom. inval.

#### Surirella subrugosa Cocquyt & R. Jahn, nom. nov.

≡ Cymatopleura solea var. rugosa O. Müll. in Bot. Jahrb. Syst. 34: 23, fig. 3. 1904.

≡ Cymatopleura rugosa (O. Müll.) Cocquyt & R. Jahn in Pl. Ecol. Evol. 147 (3): 416. 2014.

**Lectotype** (designated in Cocquyt and Jahn 2014). B 40 0040252 [http://herbarium. bgbm.org/object/B400040252] (the valve representing the lectotype was published as fig. 3D–E in Cocquyt and Jahn 2014) "Malawi, Lake Malombe, after discharge of Lake Malawi".

http://phycobank.org/100098

Nomenclatural comment. The new epithet was chosen because of *Surirella rugosa* Bramb. & P.B. Ham.

#### Unrevisable and unrevised taxa

*Surirella acanthophora* Giffen in Beih. Nova Hedwigia 21: 145, pl. 4: figs 92–95. 1966. Holotype. Giffen collection 30/6 "Fort Hare, Cape Province" South Africa.

- Surirella asperrima f. rokuprensis Woodhead & Tweed in Rev. Algol. N. S. 5: 144, fig. 4. 1960, nom. inval.
- Locality. "Sierra Leone, Rokupr" (Several localities are cited but no type is indicated McNeill et al. 2012, Art. 40.1).

Comment. Taxon unrevisable according to Cocquyt et al. (2013).

Surirella capensis Ehrenb. ex Cocquyt & R. Jahn in Cryptog. Algol. 26: 150. 2005.

- Lectotype (designated by Cocquyt and Jahn 2005b). BHUPM 130715 b "Lacus in monte Camdebo Graaf Reinet proximo, Provincia Capensis, Africa Meridionalis".
  *Surirella capensis* Ehrenb., Mikrogeologie 245, 254. 1854, nom. inval.
- Taxonomical comment. Species closely related to *Surirella sparsipuncatata* and *Iconella anassae*. Further studies are needed, including SEM to evaluate its taxonomic position, which is only possible if material from the type locality can be obtained; otherwise unrevisible.
- Surirella cuspidata f. constricta Hust. in Explor. Parc Natl. Albert. Mission H. Damas 8: 155, pl. 15: fig. 11. 1949.
- Lectotype (cited as holotype but in fact designated by Simonsen 1987). BRM 244/34a DR Congo "Belg. Kongo. 39. Karisimbi-See. +3800 m".
- Comment. Sampling site is located very probably on the Rwandan side of the border with DR Congo.
- Taxonomic comment: S. cuspidata Hust. in Int. Rev. Hydrobiol. Hydrogr. 42: 156, figs 391–393. 1942, described from Indonesia was transferred to Stenopterobia cuspidata (Hust.) Vyverman in Bull. Soc. Bot. Belgique 122: 74. 1989. Further studies are needed to evaluate Hustedt's forma and its taxonomic position.
- Surirella engleri f. densecostata R. Maillard in Bull. Mus. Natl. Hist. Nat. [Paris], Bot. 30: 39, 43 Pl. 3: fig. 1. 1977, nom. inval.
- Localities. Mali "Congo et Mozambique" (Several localities are cited but no type is indicated McNeill et al. 2012, Art. 40.1).
- Surirella engleri f. sierra-leonensis Woodhead & Tweed in Hydrobiologia 12: 202. 1958, nom. inval.
- Locality. Sierra Leone: R. Makoke at Maranda (see Cocquyt et al. 2013).
- Surirella fuellebornii var. worthingtonii H.Bachm. in Ber. Schweiz. Bot. Ges. 42: 707, 709, pl. 26: fig. 7, 8. 1933.
- Locality. Lake Victoria "Victoria Nyanza".

Surirella gracilis var. africana Cholnoky in Hydrobiologia 7: 184, fig. 82, 83. 1955.
Syntype localities. Rayton-vlei 30 km E of Pretoria, South Africa, "Tümpelchen" and "Bächlein" leg. Cholnoky.

Surirella gracilis f. constricta Cholnoky in Hydrobiologia 7: 184. 1955.

Type indicated. 10–12 km N of Rayton, 30–35 km NE of Pretoria, South Africa "Leeufonstein Quellen"

Surirella ignota Cholnoky in Nova Hedwigia 2: 118, figs 342, 343. 1960.

Type indicated. "Port Shepstone 362, Kleiner, sickernder Seitenbach des Unzimkulwana-Flusses nahe dem Paddock-Eingange im Oribi Gorge. 22.7.1958." Surirella pseudospinifera Iltis in Rev. Algol. 10 (4): 334. 1972, nom. inval.

- Surirella acanthophora Iltis in Rev. Algol. 10 (2) 174, figs 10–12, pl. 2: fig. 3, 4. 1971, nom. inval. et nom. illeg. [non Giffen 1966].
- Localities. Chad, Mali "Mare du 3e barrage à Bol. 13°30'N, 14°43'30"E. Puits près de la mare de Latir. 13°36'N, 14°44'E" (Two localities are cited but no type is indicated McNeill et al. 2012, Art. 40.1).
- Comment. *Surirella pseudospinifera* Iltis was the intended substitute name for *Surirella acanthophora* Iltis [non Giffen 1966] but based on an invald name (McNeill et al. 2012, Art. 40.1).

*Stenopterobia recta* Woodhead & Tweed in Hydrobiologia 12: 202, fig. 72. 1958. Locality. Sierrra Leone, Lake Sofon.

Comment. Taxon unrevisable according to Cocquyt et al. (2013).

Surirella rokuprensis Woodhead & Tweed in Rev. Algol. 5: 145, fig. 5. 1960, nom. inval.

Locality. "Sierra Leone, Rokupr" (Several localities are cited but no type is indicated McNeill et al. 2012, Art. 40.1).

Comment. Taxon unrevisable according to Cocquyt et al. (2013).

*Surirella rudis* var. *sierra-leonensis* Woodhead & Tweed in Rev. Algol. 5: 146, fig. 9. 1960 Type. Mambolo (2352).

Comment. Taxon unrevisable according to Cocquyt et al. (2013).

Surirella rudis [var. sierra-leonensis] f. constricta Woodhead & Tweed in Rev. Algol. 5: 146, fig. 7. 1960, nom. inval.

Locality. Sierra-Leone (Several localities are cited but no type is indicated McNeill et al. 2012, Art. 40.1).

Comment. Taxon unrevisable according to Cocquyt et al. (2013).

*Surirella scutum* Reichelt in A.W.F. Schmidt, Atlas Diatom.-Kunde, pl. 295: fig. 4. 1913, nom. inval.

Locality. Kalahari.

Comment. Type and description of the depicted species are missing.

Surirella subrobusta Hust. in A.W.F. Schmidt, Atlas Diatom.-Kunde, pl. 353: fig. 1. 1922. Lectotype (cited as holotype but in fact designated by Simonsen 1987). BRM 4/59

"Lafirio-Fluß. Deutsch-O-Afrika" (Simonsen 1987).

Comment. Description in the caption of the plate.

Surirella schweickerdtii Cholnoky in Bot. Not. 1954: 290, figs 95, 96. 1954.

≡ Stenopterobia schweickerdtii (Cholnoky) Brassac, T.Ludwig & Torgan in Diatom Research 18: 186. 2003.

Locality. "Moosrasen auf einer kleinen Insel zwischen Gras. Debegeni" South Africa.

*Surirella taiaensis* J.R. Carter & Denny, Beih. Nova Hedwigia 73: 325, pl. 8: fig. 274. 1982. Holotype. BM 78108 "Sierra Leone, River Jong (Taia) at Njala".

*Surirella tenera* var. *minor* Cholnoky in Portugaliae Acta Biol. Sér. B, 6: 140 fig. 168. 1958. Holotype. FR 118 "In rivulo apud Modderpoort prope oppidum Nylstroom (Transvaal)".

Surirella welshii Cholnoky 1962 in Hydrobiologia 20: 337, fig. 45. 1962.

Type indicated. "Unnamed mountain stream between Piggs Peak and Mbabane, 3.7.1961, leg. H. Welsh", "Swaziland".

## Conclusion

55 taxa – formerly ranked within *Surirella* - have been transferred to *Iconella*; most of these have been shown to be endemic (Ross 1983, Cocquyt et al. 1993, Cocquyt and Vyverman 1994, Cocquyt 1998, 2000,) and many of them, especially the large species, have become planktonic in the East African great lakes (Müller 1905, Hustedt in Huber-Pestalozzi 1942, Cocquyt 1998). In addition, two taxa – formerly ranked within *Stenopterobia* – have been transferred to *Iconella*. 10 taxa have stayed within *Surirella*, (although the position of *S. sparsipunctata* has to be genetically verified), and six taxa have been transferred from *Cymatopleura* to *Surirella*. For completeness sake, 21 taxa have been listed which are either unrevised or unrevisable because missing morphological data do not allow us to decide if the raphe is raised on a keel.

When more taxa from the genera *Iconella* and *Surirella* have been studied molecularly, especially the endemic species from Africa and other tropical regions, further autapomorphies might be discovered which might support the differentiation into further groups. With the currently available data, the solution by Ruck et al (2016a, b) clarifies their phylogeny and presents a very workable approach.

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**RESEARCH ARTICLE** 



# Argyrella richardsiae, a new species of Melastomataceae from the wet miombo woodlands of south-central Africa

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#### Abstract

A new species from the wet miombo woodlands of Tanzania and Angola, *Argyrella richardsiae* Veranso-Libalah & G.Kadereit, **sp. nov**. (Melastomataceae, Melastomateae), is described and illustrated. Although the widespread *Argyrella canescens* also occurs in Tanzania and northeastern Angola, *A. richardsiae* is morphologically most similar to *Argyrella bambutorum* known only from the Northwest of Cameroon, but differs by its indumentum of glandular trichomes on the entire plant (versus a mixture of stellate and glandular trichomes in other species of *Argyrella*), leaf-blades with serrulate margins (versus entire margins in *A. bambutorum*) and lateral nerves that become faint mid-way and never reach the leaf apex (versus conspicuous lateral nerves percurrent from the base to the apex in *A. bambutorum*). A preliminary conservation status of Endangered (EN) is proposed for *A. richardsiae* following the IUCN Red List Categories and Criteria. A taxonomic key and distribution map of all *Argyrella* species is also included.

#### Keywords

Africa, Angola, Argyrella, Dissotis, Heterotis, Melastomataceae, new species, Tanzania

### Introduction

*Argyrella* Naudin was first described by Naudin (1850) and later treated by Triana (1872) as *Dissotis* sect. *Argyrella* (Naudin) Triana. Later, Fernandes and Fernandes (1969, 1970) transferred the type species *D. canescens* (E.Mey. ex Graham) Hook.f. as well as *D. angolensis* Cogn. to *Dissotis* subgen. *Argyrella* (Naudin) A.Fern. & R.Fern. These two species together with four other *Dissotis* species previously treated in "séries des *Dissotis* canescents" by Jacques-Félix (1953) were then transferred to *Heterotis* Benth. sect. *Argyrella* (Naudin) Jacq.-Fél. by Jacques-Félix (1981, 1995).

A recent molecular phylogenetic analysis of African Melastomateae by Veranso-Libalah et al. (2017) included four species previously treated in Heterotis sect. Argyrella [H. canescens (E.Mey. ex Graham) Jacq.-Fél., Heterotis angolensis (Cogn.) Jacq.-Fél. var. bambutorum (Gilg & Ledermann ex Engl.) Jacq.-Fél., H. amplexicaulis (Jacq.-Fél.) Aké Assi and Agyrella sp.]. Although the phylogenetic relationships between these species were not well-resolved, all four species formed a well-supported clade in the Bayesian inference, maximum likelihood and parsimony analyses. In addition, their study of herbarium material morphologically supported the resurrection and updated circumscription of Argyrella with six species including five new combinations. Argyrella together with Guyonia Naudin, Melastomastrum Naudin, Anaheterotis Veranso-Libalah & G.Kadereit and Tristemma Juss. belong to the 'Pseudoheterotis' clade which consists mainly of herbs with persistent calyx lobes lacking intersepalar appendages. Argyrella is closely related to the monospecific Anaheterotis but is distinguished by having stellate and/or glandular trichomes on the entire plant (glabrous in Anaheterotis), entire to serrulate leaf margins (versus densely serrate margins ending in prominent ciliate trichomes in Anaheterotis). Also, Argyrella can be distinguished from Heterotis by its erect growth (versus a decumbent habit in Heterotis), calyx-tubes with an indumentum of stellate and/or glandular trichomes [versus stalked stellate emergences in Heterotis (except in H. decumbens (P.Beauv.) Jacq.-Fél. which has simple trichomes)], and paniculate inflorescences (versus flowers solitary or in cymes in *Heterotis*). The chromosome number n = 17 in A. canescens (E.Mey. ex Graham) Harv. and A. amplexicaulis (Jacq.-Fél.) Veranso-Libalah & G.Kadereit is the same as those counted in species of Melastomastrum and Tristemma (Favarger 1952, 1962).

From our comparative study of herbarium collections through visits (BR and BRLU), loans (BR, BRLU, C, EA, MO, NHN, KEW and UPS), and online repositories: BM (http://data.nhm.ac.uk/), P (https://science.mnhn.fr/all/search), LISC (http://actd.iict.pt/) and COI (https://www.uc.pt/herbario\_digital/catalogues), we have identified a wet miombo woodland species of *Argyrella* from Tanzania and Angola that is new to science, described and illustrated herein. All measurements were taken from dried specimens. The extent of occurrence (EOO) and area of occupancy (AOO) were calculated using GeoCAT (Bachman et al. 2011), and a preliminary conservation status is proposed following the IUCN Red List Categories and Criteria (IUCN 2012). We also provide an identification key and a distribution map of the seven species presently recognised in *Argyrella*.

#### Results

### Argyrella richardsiae Veranso-Libalah & G.Kadereit, sp. nov.

urn:lsid:ipni.org:names:77163878-1 Figure 1

**Type.** TANZANIA. Katavi region: Mpanda district, 19 km on Mpanda-Uvinza road, seepage areas in tall *Julbernardia paniculata, Terminalia mollis* woodland, grey and sandy soils, 6°14'S, 30°59'E, 1100 m, 14 May 1997 (fl & fr), *S. Bidgood, D. Sitoni, K. Vollesen & C. Whitehouse 3935* (Holotype: K! [K000771858!]; isotypes: K! [K000771858!]; BR! [BR0000013189358!], C!, EA!, P! [P05222349!]).

**Diagnosis.** The new species differs from all other species of *Argyrella* by having only glandular trichomes throughout the whole plant (versus a mixture of stellate and glandular trichomes in the other species), secondary branches arising at each node and leaves generally pointing downwards. It resembles *A. bambutorum* (Gilg & Ledermann ex Engl.) Veranso-Libalah & G.Kadereit but differs by having leaf-blades with serrulate margins (versus entire margins in *A. bambutorum*) and the primary pair of lateral nerves disappearing half-way between the base and the apex (versus conspicuous lateral nerves percurrent from the base to the apex in *A. bambutorum*). *Argyrella richardsiae* also differs from the widely distributed *A. canescens* and the Angolan endemic *A. angolensis* (Cogn.) Veranso-Libalah & G.Kadereit by having many new branches or buds arising at each node (versus unbranched herb in *A. angolensis* and *A. canescens*) and leaves sessile with amplexicaul bases generally pointing downwards (versus leaves petiolate with rounded to cordate bases and generally pointing upwards in *A. angolensis* and *A. canescens*) and only glandular trichomes on the hypanthium (versus dense stellate and glandular trichomes on the hypanthium of *A. angolensis* and *A. canescens*).

**Description.** Erect herb up to 1 m tall with branches arising at each node (Fig. 1A); stems quadrangular, covered with glandular trichomes (0.3–0.7 mm) (Fig. 1B). Leaves sessile, broadly ovate, generally pointing downwards; lamina  $15-35 \times 7-22$ mm, covered with sparse glandular trichomes on both surfaces, apex acute, base amplexicaul, margins serrulate; principal nerves 5–7, lateral nerves fading about half-way from the base and never reaching the apex on the adaxial surface but reaching the apex on the abaxial surface (Fig. 1C). Inflorescence a terminal panicle of cymes with 15-25 flowers or axillary with 5–10 flowers (Fig. 1D). Two caducous bracts,  $4-6 \times 3-5$  mm, pink-mauve, covered with glandular trichomes and enclosing the calyx-tube. Calyxtube campanulate, 2.5-6 mm in diameter, covered with glandular trichomes. Calyxlobes 5, triangular, 4.5–6 mm long, persistent, margins and dorsal surface covered with glandular trichomes. Petals 5, pink,  $9-13 \times 7-8$  mm, obovate. Stamens 10, markedly unequal, anthers mauve-purple, filaments vellow, pedoconnectives pink-mauve, appendages yellow. Outer stamens 16–18 mm long, anthers 5–7 mm, filaments 5–7 mm, pedoconnective 7-8.5 mm, strongly curved, appendage ventrally tri-cuspidate, 1-2 mm (Fig. 1E). Inner stamens 9–13 mm long, anthers 3.5–5 mm, filaments 4–5 mm, pedoconnective ca. 1.5 mm long, appendage ventrally bilobed, ca. 0.5 mm (Fig. 1E).



**Figure 1.** Argyrella richardsiae, **A** habit **B** glandular trichomes **C** leaf **D** flower **E** stamens: inner stamen (left), outer stamen (right) **F** seed (drawn from *Mrs H.M. Richards & S. Arasululu* 26190 and *Bidgood et al.* 3935). Illustration by Doris Franke.

Style 22–25 mm long, glabrous. Stigma punctate. Fruit a capsule, dehiscent, ca. 6 mm long. Seeds cochleate, ca. 0.6 mm in diameter, numerous (Fig. 1F).

Additional specimens examined. ANGOLA. Huambo province: Longonjo, Lépi, Caála 1700m, 3 August 1940, (fr), *J. Gossweiler 12147* (LISC030751!, LISC030752!, LISC030753!, LISC030754!, LISC030755!, LISC030756!). TANZANIA. Mpanda district: Uruwira-Tabora road, *Brachystegia* woodland, Kambisama river, 1400 m, 30 September 1970 (fl & fr), *Mrs H.M. Richards & S. Arasululu 26190* (K!, BR!); Mlele beekeeping reserve, riverine woodland, Iloba river, 6°47'56"S, 31°37'33"E, 1562 m, 7 May 2004, *N.A. Mwangulango 1193* (MO, MJG!).

**Etymology.** The species epithet is in honour of Mary Alice Eleanor Richards (also known from her collection labels as Mrs H.M. Richards), who collected extensively in Africa from 1951 to 1974 (Polhill and Polhill 2015). Of our new species *Argyrella richardsiae*, she made a collection which is cited above in 'Additional specimens examined'.

Distribution and habitat. This species is evidently endemic to the wet miombo woodlands of Mpanda district, southwestern Tanzania and Huambo province, central Angola (Fig. 2). Miombo woodland is a significant biome covering about 10% of the African landmass (White 1983; Campbell et al. 1996, 2007). Miombo woodlands are mainly found in southern and central African countries, and are the dominant vegetation component of Angola, Zambia, Tanzania, Malawi, Mozambique and Zimbabwe (Malmer 2007, White 1983, Campbell et al. 1996, 2007). They are mainly dominated by Brachystegia Benth., Julbernardia Pellegr. and Isoberlinia Craib & Stapf trees of the subfamily Caesalpinioideae, Leguminosae. The wet miombo is found in areas of more than 1000 mm annual rainfall with an elevation of 1000-2500 m. A predominant wet miombo woodland vegetation is composed of riverine woodland along watercourses and marshes in poorly drained and/or low-lying areas, mainly characterised by alluvial soils (Campbell et al. 2007, Lupala et al. 2015). Also, wet miombo has higher tree height (typically > 15 m) and higher floristic diversity which mainly occurs in the northern part of miombo distribution: eastern Angola, northern Zambia, southwestern Tanzania and central Malawi (Frost 1996). It is likely that A. richardsiae also occurs in wet miombo woodlands of southern Democratic Republic of Congo (DRC), northern Zambia and southern Malawi and not just disjunctly between Angola and Tanzania. Argyrella richardsiae like the other Argyrella species grows in marshes.

**Conservation status.** Proposed IUCN Red List Category: Endangered (EN): B2ab (ii,iii) EOO ~79 km<sup>2</sup>, AOO 32 km<sup>2</sup>. This species is only known from four collections in seepage, marshes or riverine woodlands (wet miombo woodlands) of the Mpanda district, Tanzania and Huambo province of Angola. Although cited on the collection label *Mwangulango 1193* as a locally frequent herb in the Mpanda district, it is still a poorly collected species. As earlier suggested, *A. richardsiae* may also occur in wet miombo woodlands of southern DRC, northern Zambia and southern Malawi, but at the moment we think it is better to treat it as endangered until we are certain that this species is found in other places. Moreover, this species is only known from one collection in Angola since 1940. Generally, miombo woodlands are an important source of livelihood because they provide social, economic, and environmental benefits



Figure 2. Distribution map of Argyrella species.

such as firewood, timber, medicinal plants, food, and catchment protection, among others. According to Campbell et al. (2007) over 75 million people inhabit areas covered, or formerly covered, by miombo woodland, with an additional 25 million urban dwellers relying on miombo wood or charcoal as a source of energy. As a result, these woodlands have been and are being depleted for the harvesting of timber used for charcoal production, conversion to farmlands and fuel-wood extraction (Campbell et al. 2007, Lupala et al. 2015).

GenBank Accession Nos. KX889285 (ITS), KY248410 (*psbK-psbL*), KY284711 (*accD-psaI*) (see Veranso-Libalah et al. 2017).

**Discussion.** Argyrella richardsiae is similar to A. bambutorum but differs by having serrulate leaf margins, intersepalar appendages absent, and stamens dimorphic (versus entire leaf margins, intersepalar appendages present, and stamens isomorphic in A. bambutorum). The new species also differs from A. amplexicaulis, A. sessilis (Hutch. ex Brenan & Keay) Veranso-Libalah & G.Kadereit and A. angolensis by its many new branches or buds arising at each node (versus unbranched in A. amplexicaulis, A. sessilis and A. angolensis). Argyrella richardsiae has broadly ovate leaves versus lanceolate to linear in Argyrella canescens and A. linearis (Jacq.-Fél.) Veranso-Libalah & G.Kadereit. Also, A. richardsiae has only glandular trichomes on the entire plant and leaves generally pointing downwards versus a mixture of stellate and glandular trichomes with leaves pointing upwards in the other species.

## Key to the species of Argyrella

1	Leaf lamina ovate to broadly ovate, base sessile and amplexicaul or subsessile
	(petiole < 2 mm long) <b>2</b>
_	Leaf lamina linear or lanceolate-oblong, petiolate (petiole > 2 mm long)5
2	Leaves subsessile; intersepalar appendages present; stamens yellow, subequal
	in size (isomorphic) (Northwest region of Cameroon) A. bambutorum
_	Leaves sessile to amplexicaul; intersepalar appendages absent; stamens mark-
	edly unequal in both size and colour (dimorphic)
3	Sparingly branched herb; leaf margins entire; principal pair of lateral nerves
	conspicuous and reaching the apex on the adaxial surface; calyx-tube and
	stems with stellate-tomentose and glandular trichomes4
-	Much branched herb with buds and branches at each node; leaf margins
	serrulate; principal pair of lateral nerves fading half-way between the base
	and the apex on the adaxial surface; calyx-tube and stems with glandular
	trichomes only (Angola and Tanzania) A. richardsiae
4	Leaf lamina ovate to ovate-lanceolate, < 1 cm wide; calyx-tube with sparse
	and short stellate trichomes (Guinean region)
_	
	Leaf famina broadly ovate, > 1.5 cm wide; calyx-tube with dense stellate-
	tomentose trichomes (Sierra Leone)
5	tomentose trichomes (Sierra Leone)
5 - 6	tomentose trichomes (Sierra Leone)
5 - 6	tomentose trichomes (Sierra Leone)
5 - 6	tomentose trichomes (Sierra Leone)
5 - 6 -	tomentose trichomes (Sierra Leone)
5 - 6 -	Lear famina broadily ovate, > 1.5 cm wide; calyx-tube with dense stellate- tomentose trichomes (Sierra Leone)

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