Henckelia siangensis (Gesneriaceae): a remarkable new species from Northeast India

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Abstract
Henckelia siangensis, a new species from Arunachal Pradesh of Northeast India, is described and illustrated here. The new species is remarkably different from all other allied species by its 5-winged calyx and elliptic-ovate calyx segments. It superficially resembles H. calva in glabrous stem and petioles, but differs from it in having persistent bracts, a campanulate 5-winged calyx and a style with glandular indumentum. A detailed morphological description, photographic illustration, and distribution of the new species are presented.

Keywords
Arunachal Pradesh, flora of India, Himalaya, morphology, new taxon

Introduction

Henckelia Spreng. is a tropical genus of the family Gesneriaceae, comprising about 70 species (Kanthraj et al. 2020). The genus is distributed in the India, Bangladesh, Nepal, Bhutan, China, Myanmar, Sri Lanka, Thailand, Laos and Vietnam (Kanthraj et al. 2020). In India, the genus is so far represented by 35 species, 19 of them occurring in the Himalayas and Northeast India (Krishna and Lakshminarasimhan 2018; Borah et al. 2019; Kanthraj et al. 2020). The species of Northeast India along with others found in Sri Lanka were formerly attributed to Chirita sect. Chirita (Møller et al. 2017). They are all characterized by a caulescent habit, leaves in whorls of 2 or 3, orthocarpic
capsules dehiscing along both the upper and lower sutures and unappendaged seeds (Möller et al. 2017). During our trips to the East Siang district of Arunachal Pradesh in April of 2019, a few interesting specimens of *Henckelia* were collected. They were critically studied, consulting the type specimens housed in several herbaria and scrutiny of relevant literature. The studies revealed that our specimen is remarkably different from all other species of *Henckelia* and led us to conclude that it represents a new species. The striking yellow flowers found in this species are fairly uncommon as only three other species of *Henckelia* with yellow flowers are known from NE India (*H. pathakii*, *H. calva* and *H. dimidiata*) and two others from China (*H. shuii* and *H. xinpingensis*). But as stated by Wood (1974), corolla color in *Henckelia* can vary considerably within a single species due to edaphic factors, hence much emphasis on the corolla color is not given here. A diagnostic key to the yellow flowered species of *Henckelia* in Northeast India is presented below for easy identification. Comparison of this peculiar new species was made with a superficially allied species *H. calva*, in the glabrous nature of the stem and petioles and lanceolate bracteoles. This new species is described and illustrated here.

**Methods**

Flowering stems were collected from the field and photographed using a digital camera (Nikon COOLPIX B600, Nikon India Pvt. Ltd). GPS coordinates were recorded using Garmin GPS (Etrex 10 device, Asim Navigation India Pvt. Ltd). All collected specimens were processed using standard herbarium methods (Jain and Rao 1977) and voucher specimens were deposited in ASSAM and ARUN. Morphological observations and measurements of the new species were made on both freshly collected and dried specimens. The micro morphological characters were studied with a stereomicroscope (Leica S8APO, Leica Microsystems Inc., Germany) and were compared with those reported in the relevant literature (Clarke 1874; Clarke 1883; Hooker 1885; Chatterjee 1948; Wood 1974; Burtt et al. 1988; Weitzman et al. 1997; Wang et al. 1998; Weber et al. 2011; Middleton et al. 2013; Sinha and Datta 2016; Möller et al. 2017; Krishna and Lakshminarasimhan 2018; Borah et al. 2019; Cai et al. 2019; Sirimongkol et al. 2019; Yang et al. 2019; Bui et al. 2020; Janeesha and Nampy 2020; Kanthraj et al. 2020) and digital images of type specimens present at K, E and PE, as well as actual sheets housed at ASSAM, ARUN and CAL.

**Taxonomic treatment**

*Henckelia siangensis* Taram, D.Borah & Tag, sp. nov.

urn:lsid:ipni.org:names:77211420-1

**Type.** India. Arunachal Pradesh: East Siang District, Pasighat, 28°13’54”N, 95°13’19”E; 375 m asl., 26 April 2019, *Ojar Tāku* and *Momang Tāram* 05001 (holotype: ASSAM; isotype: ARUN). (Fig. 1)
Henckelia siangensis, new species from India

Diagnosis. The species is remarkably different from all other species of Henckelia by its 5-winged calyx and elliptic-ovate calyx segments. It is superficially similar to H. calva (C.B.Clarke) D.J.Middleton & Mich.Möller in glabrous stem and petiole as well as lanceolate bracts, but can be easily distinguished by ovate to lanceolate lamina with denticulate to serrulate margins (vs. elliptic to oblong-elliptic with entire to sub-entire and ciliate margin), peduncle 0.4–0.8 cm, glabrous (vs. 2–3 cm long, glabrescent), bracts persistent (vs. deciduous), calyx segments elliptic to ovate, raised at margins forming wings (vs. narrowly triangular to lanceolate), corolla glandular pubescent inside (vs. glabrous) and glandular hairy style (vs. puberulent).

Erect perennial herb, caulescent, 15–40 cm high, stems branched; mature stem terete, ca. 0.5 cm across, glabrous, young stem reddish brown, cylindrical. Leaves decussate; petiole terete, glabrous, slightly ridged at base, 1–6 × 0.1 cm, fleshy; lamina ovate to lanceolate, 7–10 × 2.5–4.5 cm, oblique–obtuse base, acute to shortly acuminate at apex, margin denticulate–serrate, sparsely hirsute on both surfaces, hairs hyaline, dark green above, pale green below; secondary veins 6–10 pairs, sub-opposite, obscure above, raised beneath. Inflorescence axillary, 1 flowered cymes; peduncle 0.4–0.8 cm long, glabrous; pedicel glabrous 1.8–2.3 long, ca. 0.1 cm thick; bracteoles 2, glabrous, green, opposite to sub opposite, ovate to lanceolate, 4–7 × 2–4 mm, apex acute, margin entire to sub entire. Calyx green, campanulate, 5 winged, raised at the fusion of the lobes, splitting with maturity, later turning 5 lobed up to below middle of the tube, glabrous, veins obscure, tube 0.6–0.7 cm long; calyx segments 2.0–2.3 × 0.6–1.1 cm, elliptic–ovate, margin entire, apex acute. Corolla 4.5–5 × 1.4–1.8 cm, bright yellow with three dark yellow and maroon stripes per lobe near throat, more prominent on lower lip, glabrescent outside, glandular pubescent inside (dense within tube), distinctly 2 lipped, lips divergent; upper lip 2-lobed, equal, broadly ovate, 0.4–0.6 cm × 0.5–0.7 cm, apex round, margin entire; lower lip 3-lobed, lobes sub-equal, broadly ovate, 0.7–1 × 0.5–0.6 cm, apex round, margin entire; tube 2.8–3.5 × 1.3–1.7 cm. Stamens 2, inserted 2–2.3 cm above corolla base, anthers and top of filaments maroon, glandular pubescent; anthers 0.2–0.3 × 0.1–0.2 cm, cohering face to face; filaments 0.8–1.5 × 0.1 cm, geniculate near base, knee dark pink-maroon. Staminodes 3, lateral staminodes 2, divergent (sometimes coiled), 0.4–0.7 cm long, hirsute, maroon, central staminode white, antherodes white-green, 0.2–0.3 cm long. Pistil 2.8–3.6 cm long; style glandular hairy, 1.5–1.9 cm long; stigma chiritoid, lower lip 2 lobed, lobe apex acute to obtuse; disc yellow, undulate–annular, ca. 0.1 cm high. Ovary green, glabrous to glabrescent, 1.6–2 × 0.15 cm. Capsules not seen.

Phenology. Flowering: April and fruiting: September.

Etymology. The species is named after the type locality, the Siang valley.

Vernacular name (assigned here). Libe lirak Appun (in Adi language)

Distribution. So far only known from East Siang district of Arunachal Pradesh, India.

Figure 1. *Henckelia siangensis*. A flowering stem B flower front view C flower side view (arrow indicates the bracteoles) D winged calyx (arrow indicates the wings) E dissected calyx segments F dissected corolla G stamens and staminodes H pistil (Photographs by Momang Taram).
Key to yellow species of Henckelia in Northeast India

1  Bracts cupular, concealing pedicel of flower buds..................... H. pathakii
   – Bracts free, not concealing pedicel of flower buds ...................... 2
2  Bracts denticulate, calyx sub-equal and acuminate .................. H. dimidiata
   – Bracts entire, calyx equal and acute..................................... 3
3  Bracts deciduous, calyx tubular, not-winged, triangular to lanceolate, style pubescent................................. H. calva
   – Bracts persistent, calyx campanulate, winged, segments elliptic – ovate, style glandular hairy................................. H. siangensis

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A checklist of vascular plants and uses of some species for livelihood-making in Setiu Wetlands, Terengganu, Malaysia

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Abstract
The Setiu Wetlands, a unique area with nine interconnected habitats, comprises a considerable fraction of the total Peninsular Malaysia’s wetland flora. Although botanical collecting in the area has been active in the past 10 years, only a few studies dealing with the wetland flora have been published. Thus, a detailed checklist of this area is urgently needed to ensure the continuity of its inter-relating flora and fauna, as well as the livelihood of the local people. In this work we conducted a survey of the vascular plant flora of Setiu Wetlands and investigated the most important plants used by the local communities. Our checklist accounts for 406 taxa from 277 genera and 106 families, including 24 (6%) species of ferns and lycophytes, three gymnosperms, 257 (64%) dicotyledons and 122 (30%) monocotyledons. This comprehensive plant checklist will be a primary reference for the management of the newly gazetted Setiu Wetlands State Park covering more than 400 hectares of lands and water bodies.

Keywords
coastal ecosystem, diversity, flora, local community, Malesia, useful plants
**Introduction**

Wetlands are not only among the most productive and complex ecosystems (Costanza et al. 1997), but are also known to benefit humans with significant economic and ecological values (Barbier et al. 2011). The importance of wetlands has increased tremendously following the 2004 catastrophic tsunami which affected many places severely in the Asian region. The Setiu Wetlands (SW) constitutes the largest wetland complex in the east coast of Peninsular Malaysia which is located in an arbitrary but exclusive zone referring to the larger Setiu district in Terengganu. The coastal lagoon is the largest part of the SW, stretching approximately 14 km, parallel to the coastline, from Lembah Bidong in the south up to Beting Lintang to the north, while the wetland basin covers about 23,000 ha of lands and 880 ha of water bodies (Nakisah and Fauziah 2003). In 2018, in lieu of protecting vital catchment areas and their natural heritage, the state government of Terengganu gazetted two new state parks, one of which was in the Setiu district. Driven by its importance for the local economy and the dire need to wisely manage SW for the sustainability, efforts to legally protect SW were initiated more than 20 years ago. However, it was not until recently that the state authority of Terengganu passed the Terengganu State Park Enactment 2017, under which, 432 ha of SW were gazetted as State Park in Phase 1 covering mainly the SW brackish lagoon and estuary (Fig. 1). In the near future, the gazette for three more phases of this State Park will cover possibly one of the largest coastal freshwater lakes in Peninsular Malaysia, locally known as Tasik Berombak. Tasik Berombak is hydrologically important by supplying the primary source of freshwater into the brackish lagoon of SW (Sathiamurthy 2015) which is a hub for economic and livelihood activities of the SW local community. In addition, phases 3 and 4 of the gazette intend to cover mostly mangrove islands in SW, but many issues and challenges, primarily related to land title, need to be addressed.

SW supports major wetlands ecosystem of marine, coastal vegetation, brackish and freshwater swamps with nine interconnected habitats of sea, beach, mudflats, lagoons, estuaries, rivers, islands, coastal and mangrove vegetation (Mohd Lokman and Sulong 2001; Nakisah and Fauziah 2003; Jamilah et al. 2014). The nine vegetation types (Fig. 2) including the beach-ridge vegetation or BRIS soil vegetation are lowland forest, mangrove swamp forest, peat swamp forest, freshwater swamp forest, riparian vegetation, beach vegetation, heath vegetation (coastal dunes forest), and disturbed vegetation. Each of the habitats is characterised by a unique yet intricate physical environment, supporting its biological entities. Intimate and complex interaction between wetlands, people and the environment could clearly be observed in Setiu district where most of the natural resources harvested from SW are vital for supporting local livelihoods (Faridah et al. 2015). Similar to other wetlands, SW integrity critically depends on the physical and biological environments. Vegetation or flora are the vital biological entity of the SW with many efforts conducted to document this entity (for example, Jamilah et al. 2014; Siti Fatimah et al. 2015; Razali et al. 2017; Rohani et al. 2017). Furthermore, the SW flora is edaphically adapted, for example, the BRIS soil vegetation which is largely confined to the sandy environment of Terengganu narrow coastal
stripe and such unique vegetation is not found on the west coast of Peninsular Malaysia (Jamilah et al. 2014).

Setiu lagoon supports several islets within the lagoon with healthy mangrove vegetation. However, the mangrove ecosystem here is also characterised by a relatively sandier habitat as compared to the typical mangroves on the west coast of Peninsular Malaysia such as the Matang mangroves. Setiu mangroves are not only supporting the three classes of common mangrove vegetation, namely exclusive, non-exclusive and associate (Japar 1994), but also additional vegetation associated with sand ridges. This vegetation, including vascular plants, offers significant ecosystem services, such as providing food and shelter to animals residing in the area, with many being economically important. Furthermore, Setiu lagoon, which is the longest brackish wetlands in Terengganu, includes several patches of sandy-mudflats which support a healthy community of bivalves [including *Scapharca cornea* (local name: kepah bulu) and *Meretrix meretrix* (kepah minyak)] (Wan Bayani and Zaleha 2015) that are harvested by the Setiu locals for sale (Faridah et al. 2016). Two species of seagrasses (*Halodule pinifolia* and *Halophila minor*) are recorded to thrive well here (Syarifah et al. 2008). This

![Figure 1. The boundaries (red line) of the forest to be gazetted in Setiu Wetlands as state park. Map courtesy of the Terengganu State Parks.](image-url)
seagrass-mangrove continuum is reported to be an important nursery ground for the juveniles of fishes such as grouper, and pink ear emperor fish, *Lethrinus lentjan* (Le et al. 2018). The mangroves of Setiu, and its lagoon, are also an important habitat for highly demanded mangrove crabs, *Scylla* spp. (Ikhwanuddin et al. 2010), and is the source of income for many local fishermen in the area. The geography and the vegetation cover of the area support it as a hub for aquaculture activities, covering brackish water cage culture, pond culture, pen culture especially on groupers, and also oyster farming (Suratman et al. 2014).

In terms of soil origin, the Setiu coastal plain originated from marine-based deposit, arranged in a series of ridges and depressions parallel to the shoreline (Ali and Mohamed 2007; Sathiamurthy 2015) known as BRIS (Beach Ridges Interspersed with Swales). BRIS is oligotrophic or infertile and unsuitable for agriculture (Lim 2002) partly due to extreme water retention capacity and comprises 90% sand (Mohd Ekhwan et al. 2009). However, BRIS soil supports a distinct natural vegetation formation which is different from a typical evergreen rainforest (Jamilah et al. 2013). The ridge part supports heath-like ecosystem plants, while the depression site is usually a pocket of seasonal wetland with adapted vegetation (Jamilah et al. 2011).
The nine habitats in SW are increasingly being exposed to various anthropogenic and natural pressures. This could threaten the integrity and ability of those natural ecosystems to fulfil their ecological roles for the benefit of the local community and the coastal environment. As vegetation is the most important entity of the wetlands that supports other important life forms, it is essential to highlight the diversity of flora in SW. The aims of this paper are to provide the first comprehensive checklist of vascular plants of SW, and to understand the use of wild plants for livelihood continuity and sustainability in SW. The latter also further aims to understand how the local community’s utilisation affects the plants’ sustainability, so that sustainable resource management and conservation policy for SW can be achieved.

Materials and methods

The checklist is based on the plant collections carried out by JMS, EP, SMMN and DN with the help of field assistant, MRS. More than 30 different localities were visited after 2010 in the nine different ecosystems of SW. Specimens were deposited at the Herbarium of Universiti Malaysia Terengganu (UMTP). In addition, the checklist is also based on a search of the literature (e.g., Mohd Lokman and Sulong 2001; Jamilah et al. 2014; Sitit Fatimah et al. 2015; Razali et al. 2017; Rohani et al. 2017; Pesiu 2018) as well as herbaria that store collections of specimens collected from SW, such as the Herbarium of Forest Research Institute of Malaysia, Kepong (KEP) and the Herbarium of Universiti Kebangsaan Malaysia, Bangi (UKMB). The checklist includes family, species and local names, and life forms. It also provides the conservation status according to the IUCN Red List of Threatened species (IUCN 2020), Malaysia Plant Red List, Peninsular Malaysia Dipterocarpaceae (Chua et al. 2010), Malaysia Biodiversity Information System (MyBIS) and Convention on International Trade on Endangered Species of Wild Fauna and Flora (CITES).

A total of 188 houses from six villages, i.e. Beting Lintang, Gong Batu, Pengkalan Gelap, Fikri, Mangkok and Penarek, were opportunistically selected for a rapid livelihood survey to determine their dependence on SW wild flora resources. In addition to that, a stratified sampling of 10 households belonging to identified resource users was later conducted in Beris Tok Ku, to provide a better representation of wild flora resource utilisation in the area.

Results and discussion

Families, genera and species diversity

We recorded 406 taxa (400 species, three varieties and three hybrids) from 277 genera and 106 families of vascular plants in the nine habitats of SW, including 24 species of ferns and lycophytes, three species of gymnosperms (*Cycas edentata*, *Gnetum cuspidatum*...
and *G. gnemon*), with 257 being dicotyledons, and 122 monocotyledons (Table 1). This represents 19% of 2168 species recorded growing in wetlands of Peninsular Malaysia (Said and Zakaria 1992) and also illustrates the fact that SW flora is relatively species rich. The most speciose family recorded from SW is Orchidaceae (56 species/28 genera), followed by Rubiaceae (24 species/20 genera) and Fabaceae (22 species/17 genera) (Fig. 3), while there are 43 families represented only by a single species e.g., Amaryllidaceae, Commelinaceae, Cycadaceae, Dioscoreaceae, Flagellariaceae and Pittosporaceae (see Appendix 1 for other families). Among the genera that contribute most to the total number of species are *Dendrobium* (11 species), *Bulbophyllum* and *Syzygium* with 10 species, while *Bruguiera*, *Cyperus* and *Sonneratia* have five species each. In terms of the life forms (Table 2), trees have the highest percentage (39.7%) followed by terrestrial herbs and epiphytes with 16.5% and 13.3% of the taxa, respectively. Apart from the trees, the herbaceous species which can be terrestrial, epiphytic or climbing, are represented by 27.8% of the species, which implies that trees and herbaceous flora are the most important components of the SW areas.

The Orchidaceae (Fig. 4) are well represented in SW, representing 23% of 245 orchid species recently reported in Terengganu (Besi et al. 2019). Thus, to date, there are 56 species of orchids found in SW from which 14 species were recorded by Siti Fatimah et al. (2015) and 42 represent new records in SW, mostly being recent collections by Dome Nikong. The highest number of orchid species in SW, as expected, are in the widespread genera *Bulbophyllum* and *Dendrobium*, similar to the results of Besi et al. (2019) in Tasik Kenyir logging sites. Both genera are found to be most abundant epiphytic orchids growing in disturbed and logged forests in which the weather and microclimate are favourable for growth and reproductive processes. However, orchid density is due in part to the severity of the disturbance in which highly disturbed logging sites harbour lower density than somewhat disturbed sites (Besi et al. 2019). Among the species recorded in SW, there are some that are exceptional. The orchid diversity in SW is enriched with the sighting of the uncommon *Papilionanthe hookeriana* that is confined to the freshwater swamp area of Tasik Berombak in SW. It usually coexists with shrubs and tall grasses for support (Pridgeon et al. 2014). On the other hand, the discovery of *Vanilla griffithii* in its uncharacteristic habitat of the BRIS forest signified its capability to thrive in xeric environment and supported its local genus distribution pattern suggested by Mohd Raffi et al. (2014) which was best described as constantly sparse, widespread and in many habitats.

As for the mangroves, there are about 33 exclusive mangrove species including three hybrids i.e. *Sonneratia × hainanensis*, *Bruguiera × rhynchopteta*,

### Table 1. Number of families, genera and species from Setiu Wetlands, Terengganu.

<table>
<thead>
<tr>
<th>Families</th>
<th>Genera</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferns and lycophytes</td>
<td>12</td>
<td>16</td>
</tr>
<tr>
<td>Gymnosperms</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Dicotyledons</td>
<td>73</td>
<td>191</td>
</tr>
<tr>
<td>Monocotyledons</td>
<td>19</td>
<td>70</td>
</tr>
<tr>
<td>Total</td>
<td>106</td>
<td>277</td>
</tr>
</tbody>
</table>
Figure 3. The 12 largest families and genera of the vascular plants of Setiu Wetlands.

Table 2. Number of species from Setiu Wetlands according to their life form.

<table>
<thead>
<tr>
<th>Life form</th>
<th>No. of species</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trees</td>
<td>161</td>
<td>39.7</td>
</tr>
<tr>
<td>Terrestrial herbs</td>
<td>67</td>
<td>16.5</td>
</tr>
<tr>
<td>Epiphytic herbs and shrubs</td>
<td>54</td>
<td>13.3</td>
</tr>
<tr>
<td>Shrubs</td>
<td>39</td>
<td>9.6</td>
</tr>
<tr>
<td>Climbing herbs and shrubs</td>
<td>33</td>
<td>8.1</td>
</tr>
<tr>
<td>Ferns</td>
<td>23</td>
<td>5.7</td>
</tr>
<tr>
<td>Aquatic herbs</td>
<td>15</td>
<td>3.7</td>
</tr>
<tr>
<td>Palms</td>
<td>5</td>
<td>1.2</td>
</tr>
<tr>
<td>Parasitic herbs and shrubs</td>
<td>5</td>
<td>1.2</td>
</tr>
<tr>
<td>Palm-like (Pandanus spp.)</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>
| Total                            | 406            | 100            

*Rhizophora × annamalayana* and four individuals of *Bruguiera hainesii* located at Pulau Layat (Razali et al. 2017). However, the mangroves in SW and on the east coast of Peninsular Malaysia, in general, are not so diverse and widely distributed as compared to the west coast because the former are exposed to the lagoons and rivers (Latiff and
Faridah-Hanum 2014), and are also threatened by strong waves during monsoon months as well as anthropogenic activities e.g., many mangroves in SW had been uprooted to make way for aquaculture, shrimp ponds and constructions of infrastructures.

The relatively species rich profile of SW reflects on the interconnected forest types in SW which consists of different plant communities (Fig. 5) including beach, mangroves, peat swamp and freshwater swamp plants. Beach vegetation includes Casuari-naceae and Convolvulaceae and mixed mangroves plants such as the families Avicenniaceae, Lythraceae and Rhizophoraceae. Peat swamp plants can be found behind the mangrove belt and further inland, Melaleuca swamp forest dominates the waterlogged area associated with BRIS soil (Jamilah et al. 2015). On the other hand, the heath-like dune landscape established on the ridge areas of Setiu coast is characterised by stunted and low stature vegetation growing in a clumping pattern (Jamilah et al. 2014). The vegetation on the sandy and dry ridge is dominated by Myrtaceae family (Melaleuca cajuputi, Bateckea frutescens, Rhodomyrtus tomentosa and Syzygium spp.). Woody epiphytic shrubs (e.g., Ficus deltoidea) and herbaceous species such as orchids are adapted to grow underneath the clump on BRIS soil dune landscape (Jamilah et al. 2014).

However, the natural ecosystem on BRIS soil ridge and swamps is becoming scarce and smaller in coverage due to various threats faced by the coastal ecosystem of SW. It has become more scattered and fragmented, resulting in difficulty in finding an area that could be a good representative of BRIS soil flora. Fragmentation and degradation also expose this natural ecosystem to the invasion of exotic invasive alien species, such as Acacia mangium, A. auriculiformis and their hybrids (Jamilah et al. 2014). It is predicted that without legal protection and authority commitment to conserve BRIS soil natural vegetation, it will soon be replaced by these alien species, particularly Acacia spp. Although the gazettement of BRIS soil habitat is still underway, land conversion in BRIS is rampant and to prevent further land uses, ecotourism activity is recommended. Therefore, the hope is that in the near future, BRIS soil habitat would be included in the next phases of State Park gazettement which will likely have a significant effect in ensuring the conservation of this unique habitat.

As for the wetland or swamp, a rainfed swamp with a water table is highest during the monsoon months. The swamp is dominated by Melaleuca cajuputi trees with larger diameter of M. cajuputi trees relative to trees growing on the drier ridge of BRIS soil, as it grows better in waterlogged conditions as compared to dry sites (Suzuki 1999). This Melaleuca swamp harbours carnivorous species of pitcher plants (Nepenthes spp.), sundews (Drosera burmannii in particular) and Utricularia bifida which are adapted to freshwater swamp. The hydrological contribution of patches of Melaleuca swamp as a seasonal wetland is worth exploring and the wetlands may provide a critical ecosystem service of mitigating floods, particularly in monsoon months in Terengganu (Jamilah et al. 2015). In addition, SW also harbours a large freshwater lake, locally known as Tasik Berombak. The water is contributed by rain and a few small river tributaries (Sathiamurthy 2015) and comprises BRIS soil with heath-like vegetation on its ridge, but is less rich than natural BRIS ecosystem. The lake is invaded by thick bush of Han-guana malayana and other aquatic and semi aquatic non vascular plants.
Figure 5. Different plant communities in Setiu Wetlands. A Mangrove plants B Nipa palm (Nypa fruticans) population C Ceriops zippeliana D Pandanus tectorius E Ant plant, Hydnophytum formicarum attached to Bruguiera hainesii F Nepenthes ampullaria G Hoya coronaria H Ploiarium alternifolia.
The high diversity of wild orchids and other potentially useful plant species on coastal habitat of SW is indeed a natural capital for SW State Park and furthermore, the habitat supports an option value, which could be tapped in the future as outlined in Total Economic Value (TEV) (Costanza et al. 1997). The biodiversity resources in SW can be managed sustainably to support the local community green economy as an alternative to unsustainable economic activities such as sand mining. The SW State Park will also be crucial to protect the critically endangered Painted Terrapin (*Batagur borneoensis* (Schlegel & Muller, 1844)) and to serve as a refuge for some 29 mammals, 161 birds and 36 reptiles and amphibians (WWF-Malaysia). Furthermore, it is also classified as an Important Bird Area (IBA) by Birdlife International.

**Conservation status**

Eight species have been classified as threatened species including one Critically Endangered (CR), *Bruguiera hainesii*, two Endangered (EN), *Anisoptera marginata* and *Pterocarpus indicus*, and five Vulnerable (VU) (*Avicennia rumphiana*, *Halophila becchari*, *Intsia bijuga*, *Ternstroemia wallichiana* and *Vatica pauciflora*). The Critically Endangered, *B. hainesii* is only found in several localities in Southeast Asia including SW, and the lower estimates of mature individuals probably due to the low rates of propagation and germination (Polidoro et al. 2010). However, recent molecular analyses revealed that *B. hainesii* did not merit recognition of species as it has no unique haplotype/allele of its own but instead shared nuclear allele with *B. cylindrica* and *B. gymnorrhiza*, and thus indicating the hybrid origin of *B. hainesii* (Ono et al. 2016). Five species partially met the classification thresholds under the threatened species category and therefore were listed as Near Threatened i.e. *Cycas edentata*, *Myristica lowiana*, *Olax scandens*, *Phoenix paludosa*, *Sonneratia ovata*, while 155 species are regarded either as Least Concern (LC) or Data Deficient (DD). However, about half of the vascular plants (59%) occurring in SW have not been assessed and categorised under the IUCN Red List of Threatened Species.

For the Malaysia Plant Red List, two species have been classified as threatened species, namely *Anisoptera marginata* (EN) and *Anodendron candolleanum* (VU). There were nine species listed as Near Threatened i.e. *Cycas edentata*, *Cerbera odollam*, *Cerbera manghas*, *Vatica pauciflora*, *Drosera burmannii*, *Xylocarpus moluccensis*, *Horsfieldia irya*, *Myristica lowiana*, *Olax scandens* while 32 species were listed as Least Concern (LC). The other 369 species have not been assessed and categorised under the Malaysia Plant Red List but are available in MyBIS. On the other hand, there were 55 species (13%) listed under CITES of which 49 species were from Orchidaceae, three from Nepenthaceae, two from Ebenaceae and one from Cycadaceae. Almost all the orchids recorded (89%) in SW are listed in CITES. About 30,000 plant species have been listed and protected by CITES against over-exploitation through international trade of which more than half of the species assessed are orchids and cacti.
Wild flora based livelihoods in SW

We found that in the SW, the local households’ utilisation mainly focused on three species, namely *Nypa fruticans* (nypa), *Lepironia articulata* (Blue-grey sedge) and *Pandanus tectorius* (Sea Pandan, Sea screwpine). Figure 6 shows the number of flora user households based on the species utilised in each village. *Nypa fruticans* records the highest number of users with 34 households from five out of seven villages. *Lepironia articulata* is a close second, with recorded utilisation in 28 households in five villages as well. Meanwhile *P. tectorius* is the least utilised of the three species with only nine user households in total from four villages. The wide use of *N. fruticans* coincides with the highest variety of products that can be made using its various plant parts (see Fig. 7). The nypa palm is the most versatile wild plant among the three as different parts of the plant are used to make different kinds of products. For example, the young leaves are used to make tobacco wrappers, its dried midrib is weaved into baskets, while mature fronds with leaves are used to make roof-thatch. The midribs of the nypa, which are unsuitable for weaving lekar baskets, are used to make brooms. Due to this, nypa is the most preferred plant species used in SW. Its utilisation is well documented in Malaysia (see Latiff 2009; Tsuji et al. 2011). It is not only an important wild resource for the Malays but also for indigenous tribes such as the Mah Meri who use nypa leaves to produce decorative items for spirit huts, altars, homes and dancers (Baba et al. 2013).
As for *Lepironia articulata*, although it can be used to make similar types of products as those made using *Pandanus tectorius*, i.e. mats and bags, its livelihood-based utilisation in Malaysia appears less recorded compared to the latter. Instead, there appears to be more documentation on its utilisation in grey water treatment (see Sim et al. 2008; Wurochekke et al. 2014). However, its utilisation is significant for the users in SW, as it supplemented up to 45% of their monthly household income and represents a strong cultural link to the local tradition for the users who are mostly exclusive (not using other flora resource) users of this resource. The 11 users from SW produced mats, six users made sacks, while 10 users made accessories’ items such as hats and bags. Our findings suggest that current utilisation is at a sustainable level thanks to the user’s knowledge about the ecology of these plants. Its use therefore poses no threat to the integrity of the state park. According to MacDonald (2009), *L. articulata* is listed among eight major species that are commonly used for weaving activities by the Plant Resources of South-East Asia (PROSEA) (Brink and Escobin 2003) due to their high suitability as a raw material for weaving activities, in particular their toughness, plasticity, sustainable strength and impermeability after being dried (Truyen et al. 2014).

The utilisation of *L. articulata* has been documented in other countries like Indonesia, Vietnam, Thailand and China where this plant is used to make handicraft or household materials such as bags, mats, baskets, and hats (Domyos and Te-Chato 2013; Truyen et al. 2014). Whereas *P. tectorius* is only used to make one type of product, i.e. mats by nine users in SW, although other types of handicrafts used to be made in the
past. Indeed, while pandan mats are produced in various parts of Malaysia (Ismail and Nawawi 2011; Baba et al. 2013) the quality of pandan mats produced by Terengganu weavers is of excellent quality (Ismail and Nawawi 2013). Therefore, it is highly probable that the weavers in SW could also produce a variety of products (Fig. 8), just as the weavers of Mah Meri tribe who are well known for producing varied, exquisite handicrafts such as purses, pouches, mats and baskets in Pulau Carey, Selangor (Baba et al. 2013). However, there needs to be a steady market demand that guarantees a good income stream, which is provided to the Mah Meri weavers by the Gerai OA, an NGO that helps market their products through fairs and online marketing.
Conclusions

Our survey indicates that the nine connected habitats in SW are relatively rich in vascular plants, harbouring nearly 20% of Peninsular Malaysia wetland flora. The current checklist is far from complete as additional species will likely be found with wider sampling coverage and additional systematic inventories. The utilisation of plant resources for the livelihood of coastal communities in SW is still significant for the three main species used in the area (*Nypa fruticans*, *Lepironia articulata* and *Pandanus tectorius*). Local communities play an important role in the sustainability of SW, so it is essential to understand their dependence on the intricate network of wetland ecosystems and their plant species to ensure that they are not overlooked in the management plans of the Setiu Wetlands State Park.

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Appendix 1

Checklist of vascular plants from Setiu Wetlands, Terengganu, Malaysia. The habitat for all species are abbreviated as MSF = Mangrove Swamp Forest; PSF = Peat Swamp Forest; RV = Riparian Vegetation; LF = Lowland Forest; HV = Heath vegetation including CDF = Coastal Dunes Forest; BV = Beach Vegetation; DV = Disturbed Vegetation; FSF = Freshwater Swamp Forest; and BRIS including Melaleuca vegetation (MV = Melaleuca vegetation). Six categories in the conservation status, EN: Endangered, VU: Vulnerable, NT: Near Threatened, LC: Least Concern, DD: Data Deficient, NE: Never Evaluated.

<table>
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<tr>
<th>Family</th>
<th>Species</th>
<th>Local Name</th>
<th>Life Form</th>
<th>Habitat</th>
<th>IUCN Status</th>
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<td>FSF</td>
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<td><em>Finlaysonia obovata</em> Wall.</td>
<td>Kalak kambing, Pelir Kambing</td>
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<td><em>Hoya carnosa</em> (L.f.) R.Br.</td>
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<td>BV</td>
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<td><em>Hoya coronaria</em> Blume</td>
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<td><em>Hoya coriacea</em> Blume</td>
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<td><em>Hoya verticillata</em> (Vahl) G.Don</td>
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<td><em>Parsonia alboflavescens</em> (Dennst.) Mabb.</td>
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<td><em>Arthrophyllum diversifolium</em> Blume</td>
<td>Tumbuh Kelapa</td>
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<td>Schefflera elliptica (Blume) Harms.</td>
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<td>Cenama Gajah</td>
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<td><em>Alstonia pneumatophora</em> Baker ex Den Berger</td>
<td>Pulai Paya</td>
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<td><em>Catharanthus roseus</em> (L.) G.Don</td>
<td>Kemunting Cina</td>
<td>Shrub</td>
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<td>Asteraceae</td>
<td><em>Melanthera biflora</em> (L.) Wild</td>
<td>Serenai Laut, Seremai, Serenah, Sunai Laut</td>
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<td>MSF, BV</td>
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<td><em>Mikania micrantha</em> Kunth</td>
<td>Selaput Tunggul</td>
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<td><em>Pluchea indica</em> (L.) Less</td>
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<td><em>Tridax procumbens</em> L.</td>
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<td><em>Avicennia alba</em> Blume</td>
<td>Api-api Putih, Api-api Hitam</td>
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<td><em>Avicennia officinalis</em> L.</td>
<td>Api-api Ludat, Api-api, Api-api Sudu</td>
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<td><em>Avicennia rumphiana</em> Hallier f.</td>
<td>Api-api Bulu</td>
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<td>Bignoniaceae</td>
<td><em>Dolichandronespathacea</em> (L.f.) K.Schum.</td>
<td>Tui, Poko Kulo, Tuj, Kulok</td>
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<td><em>Ploiarium alternifolium</em> (Vahl) Melchior</td>
<td>Riang-riang</td>
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<td><em>Calophyllum inophyllum</em> L.</td>
<td>Bintangor laut</td>
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<td><em>Calophyllum sclerophyllum</em> Vesque</td>
<td>Bitangor Jangkang</td>
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<td><em>Casuarina equisetifolia</em> L.</td>
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<td><em>Gymnosporia littoralis</em> (Backer) Jordaan</td>
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<td><em>Salacia chinensis</em> L.</td>
<td>Akar pelanduk</td>
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<td>Chrysobalanaceae</td>
<td><em>Licania splendens</em> (Korth.) Prance</td>
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<td><em>Panastemon urophyllus</em> (Wall.ex A.DC.) A.D.C.</td>
<td>Malas Siangus</td>
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<td><em>Garcinia nigrolineata</em> Planch.ex T.Anderson</td>
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<td><em>Garcinia brevirostris</em> Scheff.</td>
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<td><em>Garcinia parvifolia</em> (Miq.) Miq.</td>
<td>Beruas</td>
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<td>Combretaceae</td>
<td><em>Lumnitzera littorea</em> (Jack) Voigt</td>
<td>Teruntum Merah</td>
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<td><em>Lumnitzera racemosa</em> Willd.</td>
<td>Teruntum Putih, Teruntum Bunga Putih</td>
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<td><em>Combretum tetralophum</em> C.B.Clarke</td>
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<td><em>Terminalia catappa</em> L.</td>
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<td>Convolvulaceae</td>
<td><em>Ipomoea cairica</em> (L.) Sweet</td>
<td>Seri pagi jalar</td>
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<td>CDF, BV</td>
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<td><em>Ipomoea pes-caprae</em> R.Br</td>
<td>Tapak Kuda, Seri pagi</td>
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<td>CDF, DV, BV</td>
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<td>Dilleniaceae</td>
<td><em>Dillenia suffruticosa</em> (Griff.) Martelli.</td>
<td>Simpoh Air</td>
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<td><em>Tetracera indica</em> (Christm. &amp; Panz.) Merr.</td>
<td>Akar Mempelas Licin, Akar Mempelas, Mempelas, Mempelas Minyak, Mempelas Paya</td>
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<td><em>Tetracera scandens</em> (L.) Merr.</td>
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<td>Dioscoreaceae</td>
<td><em>Tacula leontopetaloides</em> (L.) Kuntze</td>
<td>Lekir Pasir</td>
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<td>Dipterocarpaceae</td>
<td><em>Anisoptera marginata</em> Korth.</td>
<td>Mersawa Paya</td>
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<td>Ebenaceae</td>
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<td>Buey, Kayu Arang, Kayu Arang</td>
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<td>Styphelia malayana (Jack) Spreng.</td>
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<td>Erythroxylum cuneatum (Miq.) Kurz.</td>
<td>Cinta Mula</td>
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<td>Macaranga hypoleuca (Rchb.f. &amp; Zoll.) Müll. Arg.</td>
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<td>Shirakiaopsis indica (Willd.) Esser</td>
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<td>Suregada multiflora (A. Juss.) Baill.</td>
<td>Merlimau, Limau Hantu</td>
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<td>Aganope heptaphylla (L.) Polhill</td>
<td>Ketui Besar, Omis omis</td>
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<td>Archidendron clypearia (Jack) I.C.Nielsen</td>
<td>Petai Kera</td>
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<td>Caesalpinia bonduc (L.) Roxb.</td>
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<td>Akar Kuku Tupai</td>
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<td>Canavalia rosea (Sw.) DC.</td>
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<td>Dalbergia cadenatensis (Dennst.) Prain</td>
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<td>Derris trifoliata Lour.</td>
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<td>Desmodium adscendens (Sw.) DC.</td>
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<td>Terrestrial herb</td>
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<td>Fabaceae</td>
<td>Intsia bijuga (Colebr.) Kuntze</td>
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<td>Dianella ensifolia (L.) DC.</td>
<td>Siak-siak, Akar Siak, Benjuan, Jamaka, Lenjuang, Meroyan Bangkai, Setagit, Senjuang</td>
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<td>Myricaceae</td>
<td>Morella esculenta (Buch.-Ham. ex D.Don) I.M.Turner</td>
<td>Telur Cicak, Kesami, Keteng, Lenketing</td>
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<td>Myristinaceae</td>
<td>Aegiceras corniculatum (L.) Blanco</td>
<td>Teruntun, Kacang Kacang, Kuku Helang</td>
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<td>Rapanea portariana (Wall. ex A.DC.) Mez</td>
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<td>Myristicaceae</td>
<td>Horfieldia irya (Gaertn.) Warb.</td>
<td>Pianggu, Penaranah</td>
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<td>Koena conferta (King) Warb.</td>
<td>Penaranah Hitam</td>
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<td>Knema globularia (Lamk.) Warb.</td>
<td>Penaranah Padi, Chendarah Padi</td>
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<td>Myristica lowiana King</td>
<td>Penaranah arang, Penarahan Arang Gambut</td>
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<td>Nepenthaceae</td>
<td>Nepenthes ampullaria Jack</td>
<td>Periok Kera</td>
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<td>Nepenthes gracilis Korth.</td>
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<td>Nepenthes mirabilis (Lour.) Druce</td>
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<td>Ochnaceae</td>
<td>Brackenridgea hookeri (Planch.) A.Gray</td>
<td>Bunga Kelat Merah, Mata Ketam, Kayu Luru</td>
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<td>Olax scandens Roxb.</td>
<td>Kodak Aching, Meribut</td>
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<td>Oleaceae</td>
<td>Olea brachiata (Lour.) Merr.</td>
<td>Menserah</td>
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<td>Opiliaceae</td>
<td>Champereia manillana (Blume) Merr.</td>
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<td>Canjera rheedei J.F.Gmel.</td>
<td>Chemperai Akar</td>
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<td>Passifloraceae</td>
<td>Passiflora foetida L.</td>
<td>Buah Letup, Buah Tikus, Pokok Lang Bulu, Timun Denfdang, Timun Hutan</td>
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<td>Peraceae</td>
<td>Chaetocarpus castanocarpus (Roxb.) Thwaites</td>
<td>Membatu, Bebatu, Bedik</td>
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<td>LF, PSF</td>
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<td>Pentaphylacaceae</td>
<td>Adinandra sarosanthera Miq.</td>
<td>Tetiup, Kelat Pamah, Petura Bukit, Pongpong Raya, Samak</td>
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<td>Ternstroemia walllichiana (Griff.) Engl.</td>
<td>Medang Bunga Lawang</td>
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<td>Habitat</td>
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<td>Phyllanthaceae</td>
<td><em>Antidesma cuspidatum</em> Müll.Arg.</td>
<td>Beruni, Berunai, Sebasah Bukit</td>
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<td><em>Antidesma ghaesembilla</em> Gaertn.</td>
<td>Beruni, Balong Ayam, Guncak</td>
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<td><em>Breynia racemosa</em> (Blume) Müll.Arg.</td>
<td>Hujan panas, Ambin Kera, Peringat, Saga, Sumbar</td>
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<td><em>Glochidion littorale</em> Blume</td>
<td>Jambu Kera</td>
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<td>Pittosporaceae</td>
<td><em>Pittosporum ferrugineum</em> W.T.Aiton.</td>
<td>Belalang Puak, Cemperai Ikan, Chabek Hantu</td>
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<td><em>Aegiceras corniculatum</em> (L.) Blanco</td>
<td>Kuku Lang, Kacang-kacang, Teruntun</td>
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<td><em>Ardisia crenata</em> Sims.</td>
<td>Mata ayam, Akar Bebuluh, Mata Pelandok, Sirih Puyuh</td>
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<td><em>Ardisia elliptica</em> Thunb.</td>
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<td><em>Embelia ribes</em> Burm.f.</td>
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<td><em>Rapanea porteri</em>ana (Wall. ex A.DC.) Mez.</td>
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<td>Rhizophoraceae</td>
<td><em>Bruguiera cylindrica</em> (L.) Blume</td>
<td>Berus-berus, Bakau Putih, Berus Putih</td>
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<td><em>Bruguiera gymnorrhiza</em> (L.) Lam. ex Savigny</td>
<td>Tumu Merah, Lenggadai</td>
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<td><em>Bruguiera sexangula</em> (Lour.) Poir</td>
<td>Tumu Putih, Tumu Berau, Mata Buaya, Putut</td>
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<td><em>Bruguiera hainesii</em> C.G.Rogers</td>
<td>Berus Mata Buaya</td>
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<td><em>Bruguiera x rhynochopetala</em> (W.C.Ko) N.C.Duke &amp; X.J.Ge</td>
<td>Tumu Hibrid</td>
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<td><em>Carallia brachiata</em> (Lour.) Merr.</td>
<td>Sisik Puyu, Merpuing, Meransi</td>
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<td>Ceriops tagal (Pers.) C.B.Rob.</td>
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<td>Ceriops zippeliana Blume</td>
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<td>Gynotroches axillaris Blume</td>
<td>Mata Keli, Bulu Bulu, Kandis Baru</td>
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<td>Rhizophora apiculata Blume</td>
<td>Bakau Minyak, Bakau Akik, Bakau Tandok, Bangkita</td>
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<td>Rhizophora mucronata Lam.</td>
<td>Bakau Kurap, Bakau Belukap, Bakau Gelukap, Bakau Jankar</td>
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<td>Rhizophora x annamalayana Kathir.</td>
<td>Bakau Hibrid</td>
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<td>Rhamnaceae</td>
<td>Calubrina asiatica (L.) Brongn.</td>
<td>Bidara Laut , Peria Pantai</td>
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<td>Canthium confertum Korth.</td>
<td>Kemuning Jantan</td>
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<td>Catunaregam spinosa (Thunb.) Tirveng.</td>
<td>Duri Timbang Tahil</td>
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<td>Catunaregam tomentosa (Blume ex DC.) Tirveng,</td>
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<td>Gardenia tubifera Wall. ex Roxb.</td>
<td>Mentiong Paya, Chempaka Hutan, Delima Hutan</td>
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<td>Guettarda speciosa L.</td>
<td>Sedar Malam, Bebaru Laut, Katapang Pasir</td>
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<td>Gynochtodes sublanceolata Miq.</td>
<td>Akar sulong, Akar Lampai Hitam</td>
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<td>Oldenlandia herbacea (L.) Roxb.</td>
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<td>Hydnophytum formicarum Jack</td>
<td>Kepala Berok, Sarang Semut</td>
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<td>Hypobathrum racemosum (Roxb.) Kurz.</td>
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<td>Ixora congesta R.Br.ex Hook.f.</td>
<td>Jenjarum</td>
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<td>Ixora grandifolia Zoll. &amp; Moritzi</td>
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<td>Kailarsenia tentaculata (Hook.f.) Tirveng,</td>
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<td>Morinda citrifolia L.</td>
<td>Mengkudu Daun Kecil, Noni, Mengkudu,</td>
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<td>Morinda umbellata L.</td>
<td>Mengkudu akar, Mengkudu Hutan</td>
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<td>BV,LF</td>
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<td>Ixora congesta Roxb.</td>
<td>Pecah Periok, Bunga Penaga Riam, Jarum Saluang</td>
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<td>Ixora umbellata var. multibracteata (H.Pearson ex King &amp; Gamble) Corner</td>
<td>Pecah Periok</td>
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<td>Mussaenda glabra Vahl</td>
<td>Balik Adap</td>
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<td>Myrmecodia tuberosa Jack</td>
<td>Periok Hantu</td>
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<td>Oxyccnos longiflorus (Lam.) T.Yamaz.</td>
<td>Akar Kekait, Akar Bedara Laut, Akar Duri</td>
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<td>Psychotria sarmentosa Blume</td>
<td>Akar Daldaru, Kaum Kopi</td>
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<td>Scyphiphora hydropyllacea C.F.Gaertn.</td>
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<td>Tarenna fragans (Blume) Koord. &amp; Valeton</td>
<td>Julong-julong Jantang</td>
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<td>Uncaria acida (W.Hunter) Roxb.</td>
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<td>Acronychia pedunculata (L.) Miq.</td>
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<td>Melicope lun-ankenda (Gaertn.) T.G.Hartley</td>
<td>Tenggek burung, Pepauh, Chabang Tiga</td>
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<td>Flacourtia rukam Zoll. &amp; Moritzi</td>
<td>Rukam</td>
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<td>Scolopia macrophylla (W.&amp; A.) Clos</td>
<td>Rukam Hutan</td>
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<td>Dendrotrophe buxifolia (Blume) Miq.</td>
<td>Setong Jundor</td>
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<td>Viscum orientale Willd.</td>
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<td>Viscum ovalifolium DC.</td>
<td>Dedalu Emping, Api-api</td>
<td>Parasitic shrub</td>
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<td>Palaquium obovatum (L.) Griff. Engl.</td>
<td>Taban Putih, Nyatoh, Nyatoh Putih</td>
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<td>Planchonella obovata (R.Br.) Pierre</td>
<td>Nenasi, Misi, Nyatoh Laut, Nyatoh Kuning</td>
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<td>MSF, BV</td>
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<td>Allophylus cobbe (L.) Raeusch</td>
<td>Buah Penancang, Congkol, Cungkil, Kasai, Kasai Daun Kecil</td>
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<td>Guioa bijuga (Hiern) Radlk.</td>
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<td>Guioa pleuropetris (Blume) Radlk.</td>
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# A checklist of vascular plants in Setiu Wetlands

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<tr>
<th>Family</th>
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<th>Habitat</th>
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<td><strong>Cyperaceae</strong></td>
<td><em>Bulbostylis barbata</em> (Rottb.) C.B.Clarke</td>
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<tr>
<td></td>
<td><em>Dendrobium clavator</em> Ridl.</td>
<td>Orkid Merpati</td>
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<td>MSF, BRIS</td>
<td>NE</td>
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<tr>
<td></td>
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<td>Epiphytic herb</td>
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<tr>
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<tr>
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<td><em>Dendrodlrium lastogetalum</em> (Willd.) S.C.Chen &amp; J.J.Wood</td>
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<td>Epiphytic herb</td>
<td>BRIS</td>
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<td>NE</td>
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<td><em>Eulophia graminea</em> Lindl.</td>
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<td>Orkid Harimau</td>
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<td>BRIS</td>
<td>NE</td>
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<td><em>Liparis ferruginea</em> Lindl.</td>
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<td>FWF</td>
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<td><em>Luisia jonesii</em> J.J.Sm.</td>
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<td>NE</td>
<td>NE</td>
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<td><em>Papilionanthe hookeriana</em> (Rchb.f.) Schltr.</td>
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<td><em>Pinalia atrovinosa</em> (Carr) Schuit., Y.P.Ng &amp; H.A.Pedersen</td>
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<td>Epiphytic herb</td>
<td>BRIS</td>
<td>NE</td>
<td>NE</td>
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<tr>
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<td><em>Pinalia tenuiflora</em> (Ridl.) J.J.Wood</td>
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<td><em>Polystachya concreta</em> (Jacq.) Garay &amp; H.R.Sweet</td>
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<td>Epiphytic herb</td>
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<td><em>Renanthera elongata</em> (Blume) Lindl.</td>
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<td><em>Strongyleria pantes</em>(Lindl.) Schuit., Y.P.Ng &amp; H.A.Pedersen</td>
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<td>NE</td>
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<td><em>Taeniophyllum pusillum</em> (Willd.) Seidenf. &amp; Ormerod</td>
<td>Orkid hantu</td>
<td>Epiphytic herb</td>
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<td>Family</td>
<td>Species</td>
<td>Local Name</td>
<td>Life Form</td>
<td>Habitat</td>
<td>IUCN Status</td>
<td>Malaysia Red List/ MyBIS</td>
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<td>Orchidaceae</td>
<td><em>Thrixspermum amplexicaule</em> (Blume) Rchb.f.</td>
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<td><em>Thrixspermum centipeda</em> Loure.</td>
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<td><em>Thrixspermum trichoglossii</em> (Hook.f.) Kuntze</td>
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<td>Epiphytic herb</td>
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<td><em>Vanilla griffithii</em> Rchb.f.</td>
<td>Telinga Kerbau</td>
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<td><em>Pandanus atrocarpus</em> Griff.</td>
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<td>NE</td>
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<td><em>Pandanus helicopus</em> Kurz ex Miq.</td>
<td>Mengkuang Paya, Rasau</td>
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<td>LF</td>
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<tr>
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<td><em>Pandanus tectorius</em> Parkinson</td>
<td>Mengkuang Laut, Pandan Duri, Pandan Laut</td>
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<td>MSF</td>
<td>LC</td>
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<td><em>Pandanus yuanii</em> Solms.</td>
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<td>Philydraceae</td>
<td><em>Philydrum lanuginosum</em> Banks &amp; Sol. ex Gaertn.</td>
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<td>FWS</td>
<td>NE</td>
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<td>Rumput Jari Kembong</td>
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<td>CDF,BV</td>
<td>NE</td>
<td>NE</td>
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<td><em>Chrysopogon aciculatus</em> (Retz.) Trin.</td>
<td>Kemuncup</td>
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<td>CDF,BV</td>
<td>NE</td>
<td>NE</td>
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<td><em>Chrysopogon serrulatus</em> Trin.</td>
<td>Kemuncup Besar</td>
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<td>CDF, BV</td>
<td>NE</td>
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<td><em>Cynodon dactylon</em> (L.) Pers.</td>
<td>Rumput Minyak</td>
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<td>BV, DV</td>
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<td><em>Eleusine indica</em> (L.) Gaertn.</td>
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<td>LC</td>
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<td><em>Eriachne pallescens</em> R.Br.</td>
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<td>NE</td>
<td>NE</td>
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<td><em>Imperata cylindrica</em> (L.) P.Beauv.</td>
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<td>NE</td>
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<td><em>Ischaemum muticum</em> L.</td>
<td>Rumput Tembaga Jantan, Rumput Terutus Tembaga</td>
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<td><em>Leersia hexandra</em> Sw.</td>
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<td><em>Dapsilanthus disjunctus</em> (Mast.) B.G.Briggs &amp; L.A.S.Johnson</td>
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<td>BV</td>
<td>NE</td>
<td>NE</td>
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<tr>
<td>Family</td>
<td>Species</td>
<td>Local Name</td>
<td>Life Form</td>
<td>Habitat</td>
<td>IUCN Status</td>
<td>Malaysia Red List/MyBIS</td>
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<td>Xyridaceae</td>
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<td>Lengkuas Kecil,</td>
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<td>Lengkuas Padi</td>
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<td>Alpinia galanga (L.) Willd.</td>
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<td>Alpinia oxymitra K.Schum.</td>
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</table>
Continental diatom biodiversity discovery and description in China: 1848 through 2019

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Abstract

In this paper we inventory the continental diatom taxa described from inland waters in China, from the first species descriptions dating back to 1848 through 2019. China’s geography and hydrography are complex, including the world’s highest mountains, many large rivers, salty lakes, and large karst regions. From this area, a total of 1128 taxa have been described from China over this time period. We examine the number of taxa described in ca. 20-year intervals and note the periods of time of no to few descriptions, versus time intervals with many taxon descriptions. Early on, taxon descriptions of freshwater diatoms from China were done by mostly by Europeans working alone, and the time frame of 1948 to 1967 had few descriptions, as a devastating famine and the cultural revolution impacted scientific work and productivity. B.V. Skvortzov produced a large number of taxon descriptions, during his time in residence in Harbin, later while in Sao Paulo, Brazil, and even posthumously. More recently, a wide range of labs and collaborations across China, and with a diverse array of international partners, is ushering in a new, robust era of research on the biodiversity of continental diatoms. A few areas of research and work for the future are discussed.

Keywords

new taxa, diatoms, Bacillariophyta, Skvortzov, China, continental
Introduction

Asia has received considerable attention in the context of biodiversity discovery, biogeography and resolving the evolutionary history of a variety of lineages (Gower et al. 2012). It is an area harboring many endemic species and broader lineages (López-Pujol et al. 2011; Lu et al. 2018), relicts (Wu et al. 2007; López-Pujol and Ren 2009; Li et al. 2012a) as well as extinct taxa (Fu et al. 2019; Proust et al. 2020; Zhang 2020). Many diverse lineages have originated, radiated and gone extinct in China. This is true for many groups of organisms, including continental diatoms (see Skvortzov 1937; Hustedt 1938a, b, 1939; Williams 2004; Williams and Reid 2006; Kulikovskiy et al. 2012, 2015; Hamsher et al. 2014; Kociolek 2019).

Within China, there has been a long history and much recent attention on the description of many new species and even genera from continental ecosystems across the country. Interest in continental diatoms of China extends beyond biodiversity discovery to a rich array of work related to water quality and bioassessment (e.g. Ouyang et al. 2015), impacts of eutrophication and the creation of dams (Wang and Zhang 2004; Shen et al. 2018), paleoenvironmental reconstructions (Rioual and Wang 2009) and the development of many products with diatoms (Zhang et al. 2012; Wang and Seibert 2017; Zhang 2019).

The work on biodiversity discovery, as well as ecological work and more applied studies, depends on a working knowledge of the flora that has already been documented. We have compiled and present here a listing of the continental diatoms described from China to provide these descriptive and practical projects with a historical context and a baseline against future work can be compared. This compilation of new taxa described from China, and the publications in which they were presented, can also help interpret the history and development of diatom studies in China, from the middle of the 19th century to the present.

Methods

In our work developing this compilation of names of the continental diatoms described from China, we used the current geo-political circumscription of the country recognized by the United Nations. Our definition of “continental” refers to a variety of inland waters bodies, including freshwaters as well as those with high conductivity and, to some extent, ‘salty’ waters. But we have excluded taxa described from estuaries and marine localities from our review.

The bases of this compilation are the major resources for diatom nomenclature, including Catalogue of Diatom Names (Fourtanier and Kociolek 2011), DiatomBase (Kociolek et al. 2020) and AlgaeBase (Guiry and Guiry 2020). In addition, we reviewed several of the compilations of diatoms of China (“Flora Algarum Sinicarum Aquae Dulcis”) and some primary literature that escaped the notice of these comprehensive works and summative projects. An important reference for this work is Jin
Freshwater diatom biodiversity discovery and description in China

(1951), in which the knowledge of diatoms reported from China from 1848 to 1946, noting over 1000 taxa had been reported from marine and freshwater ecosystems, is summarized. The paper lists the taxa described from China (mostly by Skvortzov up to 1946). Although Jin (1951) did not document most of the other descriptions by European authors, both prior to and concurrent with Skvortzov, and his list obviously does not include post-1946 names, it is a great (but under cited) reference from which to develop a list of diatoms from China. The Skvortzov names were checked against the check list of his taxa compiled by Gololobova (2012). All of the names documented in this work have been included in DiatomBase.

Results

Continental diatoms described from China: An overview

In the 170-year history of continental diatom discovery in China, 1128 taxa have been described at the level of species and below (Table 1). This was not a smooth, equal accumulation of species over time, and if we examine the overall time period in groups of 20-year intervals, we can see there were times when significant numbers of taxa were described. For example, the time interval of 1928 to 1947 there were 355 taxa described in 16 publications, and between 1968 and 1987, 189 taxa were described in only 13 publications. In both instances, most of the publications were by a single author (See Appendices 1 and 2). On the other hand, in the more recent period of 2000 to 2019, the highest number of taxa were described (421), and published in 99 separate publications. Many of these papers were multi-authored. Periods of low publication of new species can be found in the earliest periods (1848–1887) and in the period 1948–1967 (Fig. 1).

In the next sections, we break down the work of continental diatom discovery in China into two periods, the initial period (1848–1999) and more recent period of continental diatom discovery (2000–2019). We examine the changes in approach and productivity during these time periods and compile a list of the taxa described and the references in which they were published.

The initial period: 1848–1999

Studies on the continental diatoms of China date back to the mid 1800’s, to the work of Ehrenberg. From these initial works through ¾ of the 20th century, there were many studies that documented continental diatom taxa in China, with a few genera and many species and subspecific taxa being proposed. The majority of taxa described was at the subspecific level. In Appendix 1 we document the new genera, species and subspecific continental diatoms described from China in this time period. This list, based on more than 50 publications only, shows that there were 2 genera described from continentals of China (Amphiraphia Chen and Zhu 1983 and Porosularia Skvortzov
Neither of these genera have been reported since they were first described, and neither of these names are in use today.

Table 1 and Appendix 1 show that from 1848 until 1999, a total of 707 taxa were described from continental in China. Of these, 218 were recognized as separate species, while 489 were described as varieties and forms. These taxa were included across 48 genera. Genera with the most taxa described include *Pinnularia* (138), *Navicula sensu lato* (98), *Cymbella sensu lato* (56) and *Nitzschia* (43) and *Gomphonema* (39).

The data for this period were organized into 20-year intervals (except the last period) and show some interesting trends. The first works in which new taxa were described were penned by Europeans working alone. This included Ehrenberg being the first in 1848 and then again in 1854, but after that more than 50 years went by before another publication that included a new species described was produced. In 1906 Mereschkowsky studies diatoms from Tibet, and in 1922 Hustedt worked on diatoms from Tibet and the northwestern part of China. Starting in the late 1920’s, through the 1940’s, the description of continental diatom taxa was dominated by Boris V. Skvortzov. Williams et al. (2016) have provided insights into the life and work of Skvortzov, and Gololobova (2012) has created a checklist of the taxa described by him. Unlike his predecessors who described continental diatoms from China, Skvortzov actually lived and worked in China (though he studied from many parts of Asia, from the Philippines, Russia and to India, and further afield, and received samples from many individuals). His base was in Harbin, in Heilongjiang Province, in the northeastern part of the country. Thus, while species he described were from many areas and diverse ecosystems across China, many of the taxa described were from the northeastern part of the country. Skvortzov trained students in Harbin, and later work on diatom taxonomy in China has been carried out by three generations of scientists who can trace their academic lineages back to him. During the same time period as Skvortzov was describing many taxa, some Europeans also contributed to our knowledge of new continental diatoms, such as Skuja (1937) and Voigt (1942a, b).

In the period following Skvortzov’s large work published in 1946, only one other publication appeared (in which 8 taxa were described), until another large work on the continental diatoms of China was published by Skvortzov in 1976. From 1950 to 1976...
was a period of dramatic challenges and cultural change in China. The first occurred with the severe famine that hit the country in 1950, lasting three years. The impacts of that famine led to the deaths of tens of millions of people, and this had lasting impacts on society for many years afterwards. In addition, the Cultural Revolution, in part a reaction to the great famine, also had negative impacts on life in China, and those impacts on academics are well-documented. Thus, with the few publications produced in this time period within the narrow discipline of diatom taxonomy and biodiversity discovery, we can see the impacts of natural disasters, economic decline and political and cultural change on the output and continuation of scientific research and training.

Skvortzov left China during the cultural revolution, and ended up in Sao Paulo, Brazil. While there, he published two large works in which nearly 140 taxa were described from Chinese continental (Skvortzov 1976a, b). These were to be his last works on the topic of continental diatoms from China while he was alive. His collections have never been found (See Williams et al. 2016).
Despite his death, and the uncertainty regarding his collections, Skvortzov’s legacy lives on with the works of his students, especially Professor Bao (who is currently in Harbin) and Professor Qi (who is currently in Guangzhou), both of whom are officially retired, as well as Professor Zhang, previously of Jinan University in Guangzhou (now deceased). All of these scientists ended up forming collaborations with scientists in the USA, with C.W. Reimer at the Academy of Natural Sciences of Philadelphia (who visited Harbin and hosted Bao, Qi and Zhang in Philadelphia) and E.F. Stoermer at the University of Michigan. Professor Qi visited Reimer at the Academy in Philadelphia while attending the International Diatom Symposium there in 1982 and stayed with Stoermer at his home in Ann Arbor, while on an extended trip to the USA in 1984. These connections yielded published collaborative works (Qi et al. 1984; Stoermer et al. 1986; Bao and Reimer 1992).

In the latter part of the 20th century, we see important floristic works being published on the diatoms from Tibet, Yunnan and other localities, and some emphasis on freshwater fossil diatoms by Chinese researchers. In these books and papers, a new generation of scientists had come on the scene, and there was the initiation of an important series focused on documenting the freshwater diatom flora of the country (“Flora Algarum Sinicarum Aquae Dulcis” Qi 1995; Qi and Li 2004; Li and Qi 2010; Shi 2004, 2013; Wang and You 2018).

The recent period (2000–2019)

In the 20-year time period, from 2000 to 2019, a total of 421 taxa, consisting of 252 species and 169 subspecific taxa across 67 genera have been described from continental waters in China (Appendix 2; Table 2). In addition, 6 new genera have been described. The breadth of lineages represented in these works during this period is remarkable, since several groups of “centric” and “araphid” diatoms have been described, as well as taxa among the major raphid lineages (Eunotiales, Bacillariales, Naviculales, Cymbellales, Rhopalodioid and Surirellales) are all included. For example, new genera of centric diatoms include Edtheriotia and the new genus of araphid diatoms is represented by Tibetiella. Raphid genera are included in the Eunotiales (Sinoperonia), Naviculales (Sichuanella, Pseudofallacia) and Cymbellales (Gomphonina). New species can be found among the centrics (in the genera Cyclotella, Edtheriotia, Urosolenia, Orthoseira, and Melosira), araphids (Fragilaria, Tabularia, Diatoma and Tetracyclus) and across the raphid diatoms, including the Eunotiales (Eunotia), Bacillariales (Simonsenia, Achnanthes), Monoraphids (Achnanthidium, Platessa), Naviculoids (Germainiella, Neidium, Pinnularia. Muelleria), Cymbelloids (Cymbella, Delicata), Rhopalodioids (Epithemia) and Surirelloids (Cymatopleura, Surirella). Please note that Achnanthes, though monoraphid, has been shown to be more closely related to members of the Bacillariales (Bruder and Medlin 2008); the monoraphid condition has evolved several times in the raphid diatom lineage (Kociolek et al. 2019a). Genera with the most species described in this period include Pinnularia (76), Gomphonema, (57), Cymbella (36), Neidium (22), Amphora (23).
There is also great geographic breadth represented in these studies, with taxa being described in the northwestern portion of the country, Tibet and Yunnan, across the biodiverse regions of the karst belt extending from Yunnan to Guizhou, the central part of China, and from Hainan to the extreme Northeast.

Since 2000, there have been floristic studies that have yielded description of new taxa, such as Zhu and Chen’s (2000) tome on the diatoms of Tibet, as well as revisionary work, such as Shi’s (2004) study on gomphonemoid diatoms. While these were published in Chinese, the trend has been in more recent years for works to be published in English-language journals, such as Phytotaxa, Phycologia, Fottea, Cryptogamie: Algologie, Nova Hedwigia, and Diatom Research. Some research continues to be published in several Chinese-language journals as well.

In 2012, Kulikovskiy et al. included a paper offered by Gololobova and Kulikovskiy where they traced a manuscript submitted in the 1960’s by Skvortzov to Dr. Proschkina-Lavrenko in Moscow for publication. but the paper was, for unknown reasons, never published. In this paper, which has been published in the 23rd volume of Iconographia Diatomologica, Skvortzov presents 445 taxa, that represent either new names, transfers or new taxon descriptions. This work includes taxa from India, China, Philippines, Japan, Korea, Australia and even Cuba. For the purposes of the current work, 208 of the taxa were newly described from China, and recorded for the year of publication (2012) even though the work was submitted 4 decades previously. These new taxon descriptions were not validly published (they lacked designation of type

<table>
<thead>
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<th>Year</th>
<th>Number of taxa described</th>
<th>Cumulative number of described taxa</th>
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<tr>
<td>TOTAL</td>
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</table>
specimens) but are included here since they represent the identification and publication of new taxa in China.

In total, since 2000, the 421 described taxa were included in nearly 100 published books and papers (Table 2), nearly twice the number of publications than was published in the preceding 150 years. In some of the recent studies, observations have verified the continued presence of endemics described in earlier works (e.g. *Gomphonema eminens* Skuja in Yunnan; Liu et al. 2020; several species of *Pinnularia* from the Great A’er Mountains; Liu et al. 2018; and species of centric diatoms from Yunnan), though the population sizes of these endemic taxa are reported to be declining (Li et al. 2012b).

The degree of collaboration between Chinese researchers within and between institutions, and the inclusion of students in these works, are both striking and a demonstration that this area of research will have a fruitful period of work ahead. Amongst the senior and corresponding authors of these papers we see the impact of Skvortzov, whose academic grandchildren and great-grandchildren working on freshwater diatoms are now in Shanghai, Taiyuan, and Harbin. There are also well-established labs in Beijing, Shanghai, Kunming, Nanjing, and Jishou, whose focus may include the study of ecological and palaeoecological interpretation, as well as biodiversity discovery and description. Collaborations with non-Chinese scientists is also hallmark of this most recent era, with partners joining in these works from the U.K., Spain, Macedonia, Germany, Luxembourg, Belgium, Canada, and the USA.

**Discussion: A look ahead**

While there has been a tremendous amount of work done to document the freshwater diatom flora of China, there are still many areas across the country that await initial or additional in-depth study. Some of these areas include, Yunnan Province, the vast karst region across Yunnan/Guangxi/Guizhou provinces, the subtropical southern part of the country, Xinjiang Autonomous Region, and Tibet, to name a few. In these regions are the two biodiversity hotspots the are fully in China (Myers et al. 2000; CEPF 2019). Also, the two longest rivers in China, The Yangtze River and Yellow River, have had isolated studies, but not comprehensive analyses. There exist specialized habitats such as also high mountain ranges, waterfalls, and hot springs, to name a few, where more intensive studies are warranted.

Perhaps one of the most challenging projects, with the potential of having the least “impact” (in the way most universities or state labs would assess that notion), but the greatest impact on the discipline, would be the typification of the diatom taxa described by Skvortzov. With the location of his collection uncertain (several generations of curators have attempted to track the collection to universities and institutes in China, Russia, Brazil, and Scandinavia), it seems likely that the collection has been lost. The challenge would not only be the large number of taxa he described. There would be a huge challenge to find specimens to designate as neotypes for his taxa, or to designate illustrations of his as epitypes. If neotypification was chosen, it would present
many challenges, especially in situations where several varieties or forms were dissected from the same species, or for the large number of taxa described in his 1976 and 2012 papers, where the illustrations are of a quality that might not facilitate making positive identifications. It also appears that the collections of Chen and Zhu have been lost, and typification of their taxa will also be an important activity for taxonomists.

The loss of several important collections in China is not restricted to that country. Collections have been discarded by many universities and research institutes across the world. Currently, China does not have a national diatom collection. Such a repository might be useful in the future, as the significant, current activities of collection-building and biodiversity discovery and description, which appears to still be in a log growth phase (see Fig. 1). The fate of the collections that have been established and blossomed in a single generation in Shanghai, Harbin, Taiyuan, Beijing and other labs will always be tenuous. Having a national collection would potentially provide a repository for the country to serve future generations of scientists.

Although there is tremendous described diversity in the continental diatom flora of China, and it is likely that there is still much to do to achieve a more comprehensive knowledge of that flora, the number of strains of continental diatoms in GenBank traceable to a source in China is modest. In fact, this is all the more surprising since some groups of continental diatoms have a tremendous diversity in China, and some endemic genera in Asia have representatives in the Chinese flora (Kociolek 2019). Some of these groups include the Thalassiosiraceae and Cymbellales. In the latter group, the only endemic genera known for that lineage worldwide are from Asia and include species from China (e.g. Zhang et al. 2018). Workflows and resources will need to be developed so that the number of molecular sequences generated from Chinese taxa are commensurate with the diversity and unique nature of the flora.

Acknowledgements

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Liu Q, Kociolek JP, Wang Q-X, Fu C (2014a) Valve morphology of three species of Neidiomorpha (Bacillariophyceae) from Zoigê Wetland, China, including description of Neidiomorpha si-chuaniana nov. sp. Phytotaxa 166(2): 123–131. https://doi.org/10.11646/phytotaxa.166.2.3


Liu B, Blanco S, Huang B (2015a) Two new Nitzschia species (Bacillariophyceae) from China, possessing a canal-raphe-conopeum system. Phytotaxa 231(3): 260–270. https://doi.org/10.11646/phytotaxa.231.3.4
Liu B, Sterrenburg F, Huang B (2015b) *Gyrosigma xiamenense* sp. nov. (Bacillariophyta) from the middle intertidal zone, Xiamen Bay, southern China. Phytotaxa 222(4): 259. https://doi.org/10.11646/phytotaxa.222.4.3

Liu B, Williams DM, Huang B (2015c) *Gyrosigma rostratum* sp. nov. (Bacillariophyta) from the low intertidal zone, Xiamen Bay, southern China. Phytotaxa 203(3): 254–262. https://doi.org/10.11646/phytotaxa.203.3.4


Liu Y, Kociolek JP, Fan Y (2016) *Urosolenia* and *Acanthoceras* species from Hainan Province, China. Phytotaxa 244(2): 161. https://doi.org/10.11646/phytotaxa.244.2.4


Liu B, Williams DM, Ou Y (2017b) *Adlafia sinensis* sp. nov. (Bacillariophyceae) from the Wuling Mountains Area, China, with reference to the structure of its girdle bands. Phytotaxa 298(1): 43–54. https://doi.org/10.11646/phytotaxa.298.1.4


You Q-M, Kociolek JP, Wang Q-X (2015c) Taxonomic studies of the diatom genus *Halamphora* (Bacillariophyceae) from the mountainous regions of southwest of China, including the description of two new species. Phytotaxa 205(2): 75–89. https://doi.org/10.11646/phytotaxa.205.2.1


Appendix I

Taxa of continental diatoms described from China, 1848–1999.

*Achnanthes affinis* var. *biseriata* Skvortzov 1938c
*Achnanthes cucurbita* Skvortzov 1935
*Achnanthes fragilis* Skvortzov 1938b
*Achnanthes fukiensis* Skvortzov 1929a
*Achnanthes girinensis* Skvortzov 1935
*Achnanthes guizhouensis* Chen and Zhu 1994
*Achnanthes hedini* Hustedt 1922
*Achnanthes hankensis* Skvortzov 1929c
*Achnanthes himalayensis* Jao and Zhu in Jao, Zhu and Lee 1974
*Achnanthes inflata* var. *sinica* Skvortzov 1929a
*Achnanthes kansouensis* Skvortzov 1935
*Achnanthes linearis* var. *kankouensis* Skvortzov 1935
*Achnanthes linearis* f. *minuta* Skvortzov 1935
*Achnanthes medioconvexa* Zhu and Chen 1996
*Achnanthes mesoconstricta* Zhu and Chen 1996
*Achnanthes minutissima* var. *constricta* Skvortzov 1935
*Achnanthes pamirensis* Hustedt 1922
*Achnanthes pinnata* Hustedt 1922
*Achnanthes schmidtiana* var. *tibetica* Jao and Zhu in Jao, Zhu and Lee 1974
*Achnanthes sublinearis* Skvortzov 1938c
*Achnanthes sublinearis* var. *complexa* Skvortzov 1938c
*Achnanthes sublinearis* var. *elliptica* Skvortzov 1938c
*Achnanthes tibetica* Jao 1964
*Actinella brasiliensis* var. *curta* Skvortzov 1929c
*Actinella miocenica* Li 1988
*Amphiprora medulica* var. *sinensis* Skvortzov 1927
*Amphiraphia* Chen and Zhu 1983
*Amphiraphia xizangensis* Chen and Zhu 1983
*Amphiraphia xizangensis* var. *major* Chen and Zhu 1983
*Amphora angusta* var. *sinensis* Skvortzov 1927
*Amphora asiatica* Skvortzov 1935
*Amphora dalatica* var. *hinganica* Skvortzov 1976b
*Amphora dalatica* var. *oculata* Skvortzov 1976b
*Amphora delicatissima* f. *sinica* Skvortzov 1935
*Amphora geniculata* Hustedt 1922
*Amphora ostenfeldii* Hustedt 1922
*Amphora ovalis* f. *mongolica* Skvortzov 1930
*Amphora reniformis* Guo, Xie and Li 1997
Anomoeoneis polygramma var. rhomboides Jao 1964
Anomoeoneis polygramma var. tibetica Jao 1964
Aulacoseira dianchiensis Yang, Stoermer and Kociolek 1994
Caloneis bacillum f. latilanceolatum Zhu and Chen 1995
Caloneis chansiensis Skvortzov 1935
Caloneis fasciata var. pekinensis Skvortzov 1928a
Caloneis holstii var. tibetica Jao 1964
Caloneis hunanensis Chen and Zhu 1989
Caloneis lepidula var. angustata Skvortzov 1976a
Caloneis patagonica var. sinica Skvortzov 1938c
Caloneis schroderi var. densestriata Skvortzov 1976a
Caloneis schumanniana var. biconstricta f. minor Zhu and Chen 1995
Caloneis silicula var. hankensis Skvortzov 1929c
Caloneis silicula f. gracilis Skvortzov 1935
Caloneis silicula var. hinganica Skvortzov 1976a
Caloneis sphagnicola Skvortzov 1938b
Ceratoneis arcus var. orientalis Skuja 1937
Cocconeis placentula var. rotunda Skvortow 1928a
Coscinodiscus sinicus Skvortzov 1946
Cyclotella asterocostata Lin, Xie & Cai in Xie et al. 1985
Cyclotella asterocostata var. borealis Xie and Cai 1985
Cyclotella asterocostata var. striata Chen 1987
Cyclotella curvistriata Chen and Zhu 1985
Cyclotella florida Voigt 1942
Cyclotella hinganica Skvortzov 1976a
Cyclotella hubeiana Chen and Zhu 1985
Cyclotella kuetzingiana var. hankensis Skvortzov 1929b
Cyclotella lacunatum Hustedt 1922
Cyclotella meneghiniana var. hankiensis Skvortzov 1929b
Cyclotella meneghiniana var. hinganica Skvortzov 1976a
Cyclotella miyiensis Qi and Yang 1985
Cyclotella obliquata Qi and Yang 1985
Cyclotella rhomboideo-elliptica Skuja, 1937
Cyclotella rhomboideo-elliptica var. rounda Qi and Yang 1985
Cyclotella shanxiensis Xie and Qi 1984
Cyclotella tibetana Hustedt 1922
Cymatopleura sinensis Skvortzov 1927
Cymatopleura solea var. hankensis Skvortzov 1929c
Cymbella affinis var. elegans Mereschkowsky 1906
Cymbella amphioxys var. asiatica Skvortzov 1938e
Cymbella amoyensis Voigt 1942
Cymbella angustata var. hinganica Skvortzov 1976b
Cymbella aspera var. elongata Skvortzov 1928b
Cymbella aspera var. fossilis Skvortzov 1937
Cymbella aspera var. intermedia Skvortzov 1929c
Cymbella aspera var. manschurica Skvortzov 1928b
Cymbella aspera var. shantungensis Voigt 1942
Cymbella australica var. bankensis Skvortzov 1929c
Cymbella austriaca var. bankensis Skvortzov 1929c
Cymbella cantonensis Voigt 1942
Cymbella cantonensis var. obtusa Voigt 1942
Cymbella cesatii var. asiatica Skvortzov 1938b
Cymbella cistula var. asiatica Mereschkowsky 1906
Cymbella cistula var. heterostriata Mereschkowsky 1906
Cymbella cistula var. hinganensis Skvortzov 1928b
Cymbella cistula var. manschurica Skvortzov 1928b
Cymbella cistula var. recta Shi 1991
Cymbella cistula var. rotundata Voigt 1942
Cymbella cistula var. woosungensis Voigt 1942
Cymbella delicatula var. capitata Skvortzov 1935
Cymbella delicatula var. fasciata Voigt 1942
Cymbella delicatula var. magna Chen & Zhu in Zhu & Chen, 1994
Cymbella ehrenbergii var. apiculata Skvortzov 1976b
Cymbella ehrenbergii var. bankensis Skvortzov 1929c
Cymbella globosa Voigt 1942
Cymbella gracilis var. arcuata Voigt 1942
Cymbella gracilis var. arcuata Skvortzov 1976b
Cymbella gracilis f. crassiostriata Skvortzov 1976b
Cymbella gracilis var. kansouensis Skvortzov 1935
Cymbella gracilis f. sphagnicola Skvortzov 1938e
Cymbella heteropleura var. hinganensis Skvortzov 1976b
Cymbella lanceolata var. grossepunctata Skvortzov 1976b
Cymbella jianghanensis Shi 1991
Cymbella jilinensis Huang in Huang et al, 1983
Cymbella lacustris var. subtropica Voigt 1942
Cymbella lata var. sinica Skvortzov 1935
Cymbella muralis Skvortzov 1937
Cymbella naviculiformis f. constricta Skvortzov 1938d
Cymbella naviculiformis var. stauroptera Voigt 1942
Cymbella pavlovi Skvortzov 1938b
Cymbella perpusilla f. elongata Skvortzov 1938e
Cymbella ruttneri var. liaotungensis Skvortzov 1946
Cymbella signata var. chinensis Skvortzov 1929a
Cymbella sinica Skvortzov 1938c
Cymbella sinica var. miyiensis Qi and Yang 1985
Cymbella stuxbergii var. tumida Skvortzov 1938c
Cymbella tenuistriata Shi 1991
Cymbella tibetana Hustedt 1922
Cymbella tumidula f. recta Skvortzov 1938c
Cymbella turgida var. hinganica Skvortzov 1976b
Cymbella ventricosa var. major Skvortzov 1929c
Cymbella ventricosa var. pekinensis Skvortzov 1929a
Cymbella ventricosa f. major Mereschkowsky 1906
Denticula elegans var. hinganica Skvortzov 1976b
Diatoma shenonngia Zhang and Qi 1994
Diploneis elliptica var. hankae Skvortzov 1929b
Diploneis elliptica var. mongolica Mereschkowsky 1906
Diploneis finnica var. sinica Skvortzov 1929a
Diploneis lijingensis Huang in Huang et al. 1998
Diploneis rupestris Skvortzov 1938a
Discoplea atmosphaerica Ehrenberg 1848
Discoplea sinensis Ehrenberg 1848
Epithemia hyndmanii var. chinensis Skvortzov 1929a
Epithemia zebra var. hankensis Skvortzov 1929c
Eucocconeis hinganica Skvortzov 1976a
Eunotia anhuiensis J. Yang 1995
Eunotia arcus var. bindulata Skvortzov 1976a
Eunotia arcus var. crassistriata Skvortzov 1976a
Eunotia arcus var. hinganica Skvortzov 1976a
Eunotia arcus var. triundulata Skvortzov 1976a
Eunotia asiatica Skvortzov 1938e
Eunotia asiatica var. interrupta Skvortzov 1938e
Eunotia bigibba var. rupestris Skvortzov 1938a
Eunotia clevei var. sinica Skvortzov 1929a
Eunotia faba var. lunata Skvortzov 1976a
Eunotia faba var. minor Skvortzov 1976a
Eunotia formica var. elongata Skvortzov 1929c
Eunotia fragilariodes var. elongata Skvortzov 1929b
Eunotia gracilis var. densestriata Skvortzov 1976a
Eunotia hainanensis Zhang et Qi 1993
Eunotia hinganica Skvortzov 1976a
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Eunotia major var. asiatica Skvortzov 1929a
Eunotia major var. hankensis Skvortzov 1929b
Eunotia monodon var. asiatica Skvortzov 1936
Eunotia asiatica var. interrupta Skvortzov 1938e
Eunotia parallela f. asiatica Skvortzov 1938b
Eunotia parallela var. hinganica Skvortzov 1976a
Eunotia pectinalis var. chinensis Skvortzov 1929b
Eunotia plicata Jao 1964
Eunotia praerupta var. tibetica Mereschkowsky 1906
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<td><em>Pinnularia sinomongolica</em> var. <em>angustior</em></td>
<td></td>
<td>Skvortzov 1976a</td>
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<tr>
<td><em>Pinnularia sphagnicola</em></td>
<td></td>
<td>Skvortzov 1938e</td>
</tr>
<tr>
<td><em>Pinnularia spitzbergensis</em> var. <em>hinganica</em></td>
<td></td>
<td>Skvortzov 1976a</td>
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<tr>
<td><em>Pinnularia stauroptera</em> var. <em>chinensis</em></td>
<td></td>
<td>Skvortzov 1929a</td>
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<tr>
<td><em>Pinnularia stauroptera</em> f. <em>bankensis</em></td>
<td></td>
<td>Skvortzov 1929c</td>
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<tr>
<td><em>Pinnularia stauroptera</em> var. <em>recta</em></td>
<td></td>
<td>Skvortzov 1929c</td>
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<tr>
<td><em>Pinnularia stauroptera</em> f. <em>subcapitata</em></td>
<td></td>
<td>Skvortzov 1929c</td>
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<tr>
<td><em>Pinnularia stomatophora</em> var. <em>hinganica</em></td>
<td></td>
<td>Skvortzov 1976a</td>
</tr>
<tr>
<td><em>Pinnularia streptoraphe</em> var. <em>asiatica</em></td>
<td></td>
<td>Skvortzov 1938b</td>
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<tr>
<td><em>Pinnularia streptoraphe</em> var. <em>muscicola</em></td>
<td></td>
<td>Skvortzov 1976b</td>
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Pinnularia subborealis Hustedt 1922
Pinnularia subcapitata f. constricta Skvortzov 1938b
Pinnularia subcapitata var. sinica Skvortzov 1935
Pinnularia subcapitata f. tenua Skvortzov 1938e
Pinnularia subsolaris var. asiatica Skvortzov 1938e
Pinnularia subsolaris var. interrupta Skvortzov 1935
Pinnularia tibetana Hustedt 1922
Pinnularia tibetana var. argunensis Skvortzov 1938d
Pinnularia tibetana var. stauroneiformis Skvortzov 1946
Pinnularia tibetana var. truncata Skvortzov 1946
Pinnularia tibetica Mereschkowsky 1906
Pinnularia turizaninow Skvortzov 1976b
Pinnularia viridis f. argunensis Skvortzov 1938d
Pinnularia viridis var. fasoiaata Skvortzov 1976b
Pinnularia viridis f. hankensis Skvortzov 1929c
Pinnularia viridis var. hinganica Skvortzov 1976b
Pinnularia viridis f. hinganica Skvortzov 1976b
Pinnularia viridis var. jenisseeyensis Skvortzov 1976b
Pinnularia viridis f. muscicola Skvortzov 1976b
Pinnularia viridis var. orientalis Skvortzov 1938e
Pinnularia viridis var. sinica Skvortzov 1946
Pinnularia viridis var. ussuriensis Skvortzov 1929c
Pinnularia zabelini Skvortzov 1976b
Pinnularia zabelini var. amurensis Skvortzov 1976b
Pinnularia zabelini var. dimidia Skvortzov 1976b
Pinnularia zabelini var. zeana Skvortzov 1976b
Pinnularia zabelini var. interrupta Skvortzov 1976b
Pleurosigma spenceri var. sinensis Skvortzov 1927
Pleurosigma spenceri var. tientsinensis Skvortzov 1927
Porosularia Skvortzov 1976b
Porosularia amoyensis Skvortzov 1976b
Porosularia borgei Skvortzov 1976b
Porosularia calawayi Skvortzov 1976b
Porosularia calawayi var. undulata Skvortzov 1976b
Porosularia chowyiliangi Skvortzov 1976b
Porosularia handel-mazzettii Skvortzov 1976b
Porosularia jurilyi Skvortzov 1976b
Porosularia jurilyi var. striata Skvortzov 1976b
Porosularia kolbei Skvortzov 1976b
Porosularia lackeyi Skvortzov 1976b
Porosularia liouningyanii Skvortzov 1976b
Porosularia meisteri Skvortzov 1976b
Porosularia merrilli Skvortzov 1976b
Porosularia poretskyi Skvortzov 1976b
Porosularia poroidea Skvortzov 1976b
Porosularia pseudoviridis Skvortzov 1976b
Porosularia pulchra Skvortzov 1976b
Porosularia scheshukewii Skvortzov 1976b
Porosularia skujae Skvortzov 1976b
Porosularia skujae var. unilateralis Skvortzov 1976b
Porosularia striata Skvortzov 1976b
Porosularia subsalsa Skvortzov 1976b
Porosularia wislouchi Skvortzov 1976b
Rhopalodia gibba var. gracilis Skvortzov 1976b
Rhopalodia gibba var. major Skvortzov 1928b
Rhopalodia gibberula f. mongolica Mereschkowsky 1906
Rhopalodia gibberula f. tibetica Mereschkowsky 1906
Rhopalodia pseudogibba Skvortzov 1976b
Rhopalodia tibetica Mereschkowsky 1906
Schizostauron sorokninii Mereschkowsky 1906
Scoliopleura pavlovii Skvortzov 1930
Stauroneis anceps var. hankensis Skvortzov 1929c
Stauroneis anceps var. oblonga Skvortzov 1929c
Stauroneis anceps var. orientalis Skvortzov 1929c
Stauroneis anceps var. hinganica Skvortzov 1976a
Stauroneis anceps var. kansouensis Skvortzov 1935
Stauroneis anceps var. usuriensis Skvortzov 1929c
Stauroneis chinensis Skvortzov 1929b
Stauroneis gregori var. hankensis Skvortzov 1929c
Stauroneis jimeiensis Lin 1989
Stauroneis laticeps Hustedt 1922
Stauroneis okamurae Skvortzov 1929c
Stauroneis parvula var. rupestris Skvortzov 1937
Stauroneis phoenicenteron f. curta Skvortzov 1929c
Stauroneis phoenicenteron var. genuina Skvortzov 1928b
Stauroneis phoenicenteron var. hankensis Skvortzov 1929c
Stauroneis phoenicenteron f. hankensis Skvortzov 1929c
Stauroneis phoenicenteron var. oblongella Skvortzov 1929c
Stauroneis rupestris Skvortzov 1938a
Stauroneis tibetica Mereschkowsky 1906
Staurophtera granulata Ehrenberg 1848
Stenopterobia sigmoidea Skvortzov 1976
Stephanodiscus sinensis Ehrenberg 1854
Stephanodiscus soochowensis Skvortzov 1946
Surirella alisoviana Skvortzov 1929c
Surirella angusta var. amoyensis Skvortzov 1929b
Surirella angusta var. constricta Skvortzov 1929c
Surirella angusta var. curta Skvortzov 1929c
Surirella angusta var. elongata Skvortzov 1929c
Surirella angusta var. hankensis Skvortzov 1929b
Surirella angusta f. ovata Skvortzov 1929c
Surirella biseriata var. orientalis Skvortzov 1929c
Surirella biseriata var. ussuriensis Skvortzov 1929c
Surirella borscowi Mereschkowsky 1906
Surirella capronii var. hankensis Skvortzov 1929c
Surirella chachinae Skvortzov 1929c
Surirella didyma var. hinganica Skvortzov 1976b
Surirella elegans var. hankensis Skvortzov 1929c
Surirella elliptica Ehrenberg 1848
Surirella engleri var. hankensis Skvortzov 1929c
Surirella fukiensis Skvortzov 1929a
Surirella hinganica Skvortzov 1976b
Surirella linearis var. vermifera Skvortzov 1938c
Surirella ovalis var. hankensis Skvortzov 1929c
Surirella ovalis f. tientsinensis Skvortzov 1927
Surirella ovata f. curta Skvortzov 1930
Surirella ovata f. mongolica Skvortzov 1930
Surirella patella var. hankensis Skvortzov 1929c
Surirella robusta var. hankensis Skvortzov 1929c
Surirella robusta var. manschurica Skvortzov 1928b
Surirella saxonica var. sinica Skvortzov 1929a
Surirella splendida var. hankensis Skvortzov 1929c
Surirella tenera var. hinganica Skvortzov 1976b
Surirella tibetica Mereschkowsky 1906
Surirella tientsinensis Skvortzov 1927
Surirella ussuriensis Skvortzov 1929c
Surirella ussuriensis var. elegans Skvortzov 1929c
Surirella ussuriensis var. elongata Skvortzov 1929c
Synedra affinis var. sinica Skvortzov 1935
Synedra amphicephala var. asiatica Skvortzov 1935
Synedra licenti Skvortzov 1935
Synedra mazamaensis var. changbaiensis Bao and Reimer 1992
Synedra rumpens var. sinica Skvortzov 1935
Synedra tenera var. sinica Skvortzov 1935
Synedra ulna f. constricta Skvortzov 1938c
Synedra ulna f. curta Skvortzov 1928c
Synedra ulna var. anhuiensis Yang 1990
Synedra ulna var. intermedia Mereschkowsky 1906
Synedra ulna var. lanceolata f. constricta Skvortzov 1938c
Synedra ulna var. mongolica Skvortzov 1928c
Synedra ulna var. tenuirostris Skvortzov 1938c
Synedra vaucheriae var. capitata Skvortzov 1938c
Tetracyclus celatom var. minor Li 1999
Tetracyclus dunhuanensis Li 1984
Tetracyclus ellipticus var. austrochinensis Zhang 1994
Tetracyclus ellipticus var. ovaliformis Li 1984
Tetracyclus ellipticus var. rostrata Li 1984
Tetracyclus jaoi Li 1984
Tetracyclus minutus Li 1999
Tetracyclus mucronatus Li 1999
Tetracyclus navicularis Li 1984
Tetracyclus ovaliformis Li 1984
Tetracyclus radiatus Li 1999
Tetracyclus rupestris var. subcylpeatus Li 1999
Tetracyclus shangduensis Li 1984
Tetracyclus sinensis Li 1984
Tetracyclus subcylpeus Li and Williams 1990
Tetracyclus subdivisium Williams and Li 1990
Tetracyclus subdivisium var. ellipticus Li 1999
Thalassiosira lacustris var. crassiospinua Cai et Xie in Xie and Cai 1981
Tryblionella debilis var. sinensis Skvortzov 1927
Tryblionella hantzschiana f. sinensis Skvortzov 1927
Tryblionella tryblionella Skvortzov 1929c
Tryblionella tryblionella f. hankensis Skvortzov 1929c

Appendix 2


Achnanthes chinii Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Achnanthes coarctata subsp. fukinensis Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Achnanthes dalaica Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Achnanthes drepanocladoides Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Achnanthes drepanocladoides var. fukinensis Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Achnanthes gracillima var. sinica Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
**Achnanthes hankiana** var. *sinica* Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012

**Achnanthes kansouensis** var. *septentrionalis* Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012

**Achnanthes kryophila** subsp. *distincta* Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012

**Achnanthes kryophila** var. *sinica* Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012

**Achnanthes lanceolata** var. *argunensis* Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012

**Achnanthes lanceolata** var. *elliptica* f. *asiatica* Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012

**Achnanthes linearis** var. *szechwanica* Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012

**Achnanthes minutissima** var. *bistriata* Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012

**Achnanthes maolanensis** P.Yu, Kociolek, & Q-M.You in Q-M.You et al. 2019b

**Achnanthes montana** var. *sinica* Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012

**Achnanthes pseudoexigua** Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012

**Achnanthes pseudoexigua** var. *unilateralis* Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012

**Achnanthes radiata** Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012

**Achnanthes rarissima** Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012

**Achnanthidium epilithica** P.Yu, Q-M.You & Q-X Wang in Yu et al. 2019c

**Achnanthidium guizhouensis** P.Yu, You & Kociolek in You et al. 2019a

**Achnanthidium jiuzhaiensis** P.Yu, Q-M.You & Q-X Wang in Yu et al. 2019c

**Achnanthidium lacustre** P.Yu, Q-M. You et Kociolek in Yu et al. 2019b

**Achnanthidium limosua** P.Yu, Q-M. You & Q-X Wang in Yu et al. 2019c

**Achnanthidium longissimum** P.Yu, Q-M.You & Kociolek in Yu et al. 2019a

**Achnanthidium mediolanceolatum** P.Yu, Q-M.You & Kociolek in You et al. 2019a

**Achnanthidium parvulum** You, Q-M.You & Kociolek in You et al. 2019a


**Achnanthidium sublanceolatum** P.Yu, Q-M.You et Kociolek in Yu et al. 2019b

**Achnanthidium subtilissimum** P.Yu, Q-M.You & Q-X Wang in Yu et al. 2019c

**Achnanthidium taipeingensis** P.Yu, Q-M.You et Kociolek in Yu et al. 2019b

**Adlafia sinensis** B.Liu & D.M.Williams in B.Liu et al. 2017

**Amphora chu-yin-changii** Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012

**Amphora dalaica** Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012

**Amphora dalaica** var. *bistriata* Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Amphora dalaica var. latostriata Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Amphora dalaica var. oculata Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Amphora delicatissima var. dalaica Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Amphora delicatissima var. pekinensis Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Amphora epithemiformis Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Amphora jao Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Amphora liouiana Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Amphora meyeri Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Amphora normanii var. alkalina Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Amphora normanii var. curta Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Amphora normanii var. curta f. mongolica Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Amphora normanii var. interrupta Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Amphora normanii var. pekinensis Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Amphora normanii var. payangi Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Amphora perpusilla var. mongolica Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Amphora perpusilla var. pekinensis Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Amphora perpusilla var. subelliptica Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Amphora subsalina Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Amphora wangchanii Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Amphora wang-wei Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Aneumastus yamdrokensis Q.Liu & S.L. Xie in Q.Liu et al. 2018
Caloneis clevei var. parallela Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Clipeoparvus tibeticus Q.Liu, Kociolek & Xie in Q.Liu et al. 2019b
Cocconeis pediculus var. cruciata Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Cocconeis pediculus var. emarginata Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Coscinodiscus rothii var. sibirica Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Coscinodiscus sinicus var. sinica Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Cyclotella changhai J.-X. Xu & J.P. Kociolek in Xu et al. 2017
Cyclotella glomerata var. argunensis Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Cyclotella kutzingiana subsp. densestria Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Cyclotella kutzingiana var. dalaica Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Cyclotella meneghiniana var. pumila fo. sibirica Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Cymatopleura elliptica var. sinica Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Cymatopleura aquastudia Kociolek & You in You et al. 2017b
Cymatopleura xinjiangiana You & Kociolek in You et al. 2017b
Cymbella chow-yi-liangii Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Cymbella cistuloides var. angulata Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Cymbella cistuloides var. angulata f. corni-caprae Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Cymbella cistuloides var. angulata f. minor Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Cymbella cistuloides var. bilateralis Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Cymbella cistuloides var. truncata Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Cymbella cistuloides var. undulata Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Cymbella dalaica Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Cymbella gracilis var. sinica Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Cymbella distalebiseriata B.Liu & D.M. Williams in B.Liu et al. 2018d
Cymbella fuxianensis Y.Li & Gong in Gong and Li 2011
Cymbella hechiensis Y.Li & W.Zhang in Zhang et al. 2019
Cymbella heihainensis Y.Li & Gong in Hu et al. 2013
Cymbella hubeiensis Y.Li Y. in Gong et al. 2013
Cymbella jianghanensis Y.Li in Gong et al. 2013 (nomen nudum)
Cymbella khokhensis Metzeltin, Lange-Bertalot & Li in Metzeltin et al. 2009
Cymbella liyangensis Zhang, Jüttner & E.J. Cox, 2018
Cymbella moelleriana var. argunica Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Cymbella pekinensis Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Cymbella paenetruncata Y.Li & Z.Gong in Gong et al. 2013
Cymbella pamirensis Z.Zhang & Rioual in Z.Zhang et al. 2017
Cymbella pseudotumida Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Cymbella pseudotumida var. psuedoborealis Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Cymbella rupicola var. sinica Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Cymbella semicircularis var. dalaica Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Cymbella sinica var. rostrata Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Cymbella sinuata var. argunensis Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Cymbella tumida var. convergentistriata Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Cymbella tungtingiana Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Cymbella pulchra Y.Li & Lange-Bertalot in Gong et al. 2013
Cymbella shii Y.Li in Gong et al. 2013
Cymbella shudunensis. Y.Li & Metzeltin in Hu et al. 2013
Cymbella sinensis Metzeltin & Krammer in Krammer 2002
Cymbella xingyunensis Y.Li & Gong in Hu et al. 2013
Cymbella yabe var. punctata Y.Li & Shi in Li et al. 2003
Cymbella yangtzensis Y.Li & D.Metzeltin in Gong et al. 2013
Cymbopleura pseudokuelbsii Shi 2013
Delicata changqingensis W.Zhang, S.Q.Yang & S. Blanco in Zhang et al. 2019
Delicata sinensis Krammer and Metzeltin 2003
Delicata williamsii B.Liu & S. Blanco in Bing Liu et al. 2018b
Diatoma kalakulensis Peng, Rioual & D.M. Williams, 2017
Diatoma rupestris Y.Liu & Wang in Y.Liu et al. 2010
Diploneis barbatula Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Diploneis parma var. sinoborealis Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Diploneis pseudoovalis var. tiensinensis Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Diploneis smithii var. denseareolata Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012

Edtheriotia Kociolek, Q.You, Stepanek, R.L.Lowe & Q-X.Wang, 2016a

Edtheriotia guizhoiana Kociolek, You, Stepanek, R.L.Lowe & Q-X.Wang 2016a
Entomoneis triundulata B.Liu & D.M.Williams in B.Liu et al. 2018c
Epithemia arguiformis Q-M. You & Q-X. Wang, 2009
Eucocconeis lichunhaii Y. Li in Y. Li and Gong 2013
Eunotia arcus var. undulata Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Eunotia bigibba var. subcapitata Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Eunotia diodon var. fukinensis Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Eunotia filiformis Luo et al. 2019
Eunotia monodon var. amoyensis Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Eunotia pectinalis var. amoyensis Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Eunotia mugecuo Luo et al. 2019
Eunotia pectinalis var. bigibba Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Eunotia pectinalis var. curta Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Eunotia pectinalis var. sinica Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Eunotia praerupta var. sinica Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Eunotia shantungensis Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Eunotia shantungensis var. linealata Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Eunotia sudeticiformis Kociolek et al. 2016b
Eunotia tauntoniensis var. amoyensis Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Eunotia tridentula var. sinica Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Eunotia valida var. densistiata Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Eunotia valida var. sinica Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Fragilaria crenophila var. sinensis Rioual in Rioual et al. 2017a
Geissleria jianghanensis Y. Li in Y. Li et al. 2005
Germainiella guizhouiana Kociolek et al. 2019b
Germainiella maolaniana Kociolek et al. 2019b
Germainiella sinica Kociolek et al. 2019b
Gomphocymbella asymmetrica Shi & Y. Li in Shi et al. 2003
Gomphocymbella laxistriata Shi & Y. Li in Shi et al. 2003
Gomphoneis distorta Q-M. You & Kociolek in Q-M. You et al. 2013
Gomphoneis pseudosubtiloides Q-M.You & Kociolek in Q-M. You et al. 2013
Gomphoneis qii Q-M.You & Kociolek in Q-M. You et al. 2013
Gomphoneis rostratoides Q-M.You & Kociolek in Q-M. You et al. 2013
Gomphoneis stoermeri Q-M.You & Kociolek in Q-M. You et al. 2013
Gomphoneis subtiloides Q-M.You & Kociolek in Q-M. You et al. 2013
Gomphonema xinjiangiana Q-M.You & Kociolek in Q-M. You et al. 2013
Gomphonema argunensis Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Gomphonema asiaticum Y.Liu & Kociolek in Y.Liu et al. 2013
Gomphonema augur var. poyangiana Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Gomphonema clevei var. oryzae Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Gomphonema constrictum var. tumidum Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Gomphonema gordejevi Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Gomphonema heideni var. mingiana Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Gomphonema intricatum var. curvatum Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Gomphonema jao Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Gomphonema kaznakowi var. mingiana Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Gomphonema bicepiformis Zhang & Kociolek, 2018b
Gomphonema bigutianchnensis Y.Li in Liao and Y.Li 2018
Gomphonema chinense Y.Liu & Kociolek in Y.Liu et al. 2013
Gomphonema constrictum var. ellipticum Z.X.Shi & J.Y.Chen in Shi 2004
Gomphonema dichotiforme Z.X.Shi, 2004
Gomphonema genestoermeri Y.Liu & Kociolek in Y.Liu et al. 2013
Gomphonema heilongtanensis Y.Li, Kociolek & D.Metzel, 2010
Gomphonema instabilis var. rhombicum S.Q.Xie & Z.H.Shi in Shi 2004
Gomphonema intricatoides Q-M.You & Kociolek, 2015
Gomphonema intricatum var. mirum Z.X.Shi & H.Z.Zhu, 2004
Gomphonema kaznakowi var. cruciatum Z.X.Shi & Y.Li in Shi 2014
Gomphonema lanceolatum var. amuricum Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Gomphonema lanceolatum var. curtum Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Gomphonema longiceps var. rupestris Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Gomphonema mediocris Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Gomphonema mediocris var. capitatum Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Gomphonema mereschkowskyii Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Gomphonema mereschkowskyii subsp. lancetulum Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Gomphonema olivaceum var. argunensis Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Gomphonema metzeltinii Q-M.You & Kociolek, 2015
Gomphonema microlanceolatum Q-M.You & Kociolek, 2015
Gomphonema montanum var. multipunctatum Z.X.Shi & H.Z.Zhu in Shi 2004
Gomphonema olivaceum var. brevistriatum Li & Shi in Y.Li et al. 2003
Gomphonema olivaceum var. brevistriatum Y.Li & Shi in Li et al. 2003
Gomphonema olivaceum var. densostriatum Z.X.Shi & H.Z.Zhu, 2004
Gomphonema olivaceum var. punctatum Z.X.Shi & N. Li in Shi 2004
Gomphonema pygmaeoides Q-M.You & Kociolek, 2015
Gomphonema rexlowei Y.Liu & Kociolek in Y.Liu et al. 2013
Gomphonema shanghaiensis Zhang & Kociolek, 2016b
Gomphonema shangtungensis var. rostratum Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Gomphonema sichuanensis Y.Li & Kociolek in Li et al. 2010b
Gomphonema staurophorum var. oblongum Li & Shi in Li et al. 2003
Gomphonema subclavatum var. elongatum Z.X.Shi, 2014
Gomphonema subinsignisformis L.Ge, Y.Liu & Kociolek, 2014
Gomphonema turriss var. elongatum Z.X. Shi & H.Z. Zhu in Shi 2004
Gomphonema turriss var. latum Y.Fan & Q-X.Wang in Fan et al. 2004
Gomphonema wangi Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Gomphonema williamsii Kociolek & Y.Liu in Y.Liu et al. 2013
Gomphonema witkowskii Kociolek & Y. Liu in Y.Liu et al. 2013
Gomphonema wuxiensis W.Zhang & Kociolek in Zhang et al. 2018
Gomphonema xiantaociicum Z.X.Shi & N.Li in Z.X.Shi 2014
Gomphonema xiantaociicum Z.X.Shi & N.Li in Z.X.Shi 2014
Gomphonema xinjiangianum Q-M.You & Kociolek, 2015
Gomphonema yangtzensis Y.Li in Y.Li et al. 2006
Gomphonema yaominae Y.Li, in Gong and Li 2012
Gomphosinica Kociolek et al. 2015
Gomphosinica capitata Kociolek, Q-M.You & Q-X. Wang in Kociolek et al. 2015
Gomphosinica lugunensis Y.Liu et al. in Cheng et al. 2018
Gomphosinica robusta Kociolek, Q-M.You & Q-X. Wang in Kociolek et al. 2015
Gomphosinica selincuoensis Z.Zhang, Q-M.You & Kociolek in Yang et al. 2019
Gomphosinica simiae Kociolek, Q-M.You & Q-X.Wang in Kociolek et al. 2015
Gomphosinica subtilis Kociolek, Q-M.You & Q-X.Wang in Kociolek et al. 2015
Gyrosigma peisonis var. major Peng, Rioual & Sterrenburg, 2016
Halamphora daochengensis Zhang, Jüttner & Levkov in Zhang et al. 2019
Halamphora hezhangii Q-M.You & Kociolek in Q-M. You et al. 2015c
Halamphora subfontinalis Q-M.You & Kociolek in Q-M. You et al. 2015c
Hannaea tibetiana Q.Liu, Glushchenko, Kulikovskiy & Kociolek in Q.Liu et al. 2019a
Hantzschia lineolata Skvortzov ex Golobobov & Kulikovskiy in Kulikovskiy et al. 2012
Hantzschia virgata var. dalaica Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Hippodonta qinghainensis Peng & Rioual, 2014
Humidophila cavernaphila Lowe, Kociolek & Q-M.You in Lowe et al. 2017
Humidophila minuta Lowe, Kociolek & Q-M.You in Lowe et al. 2017
Humidophila panduriformis Lowe, Kociolek & Q-M.You in Lowe et al. 2017
Humidophila potapovae Lowe, Kociolek & Q-M.You in Lowe et al. 2017
Humidophila undulocententa Lowe, Kociolek & Q-M.You in Lowe et al. 2017
Kolbesia sichuanensis P. Yu, Q-M. You & Q-X. Wang in Yu et al. 2019a
Lindavia khinganensis Rioual in Rioual et al. 2017
Luticola hunanensis B.Liu & D.M.Williams in B.Liu et al. 2017a
Luticola wulingensis B.Liu & S.Blanco in B.Liu et al. 2017a
Melosira asiatica Skvortzov ex Golobobov & Kulikovskiy in Kulikovskiy et al. 2012
Muellera psuedogibbula Q.Liu & Q-X.Wang in Liu et al. 2018
Navicula craticuloides Li & Metzeltin in Gong et al. 2015
Navicula gongii Metzeltin & Li in Gong et al. 2015
Navicula ignorata Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Navicula salinarum f. gracilis Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Navicula subocculata var. parallelisitiata Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Navicula wangii Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Navicula wangii f. constricta Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Navicula wangii var. obtusa Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Navicula wangii var. subcapitata Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Navicula seposita var. major Chen & Zhu in Zhu and Chen 2000
Navicula subtilissima var. paucistriata Chen & Zhu in Zhu and Chen 2000
Navicula yunnanensis Li & Metzeltin in Gong et al. 2015
Neidiomorpha sichuaniana Q.Liu, Q-X.Wang & Kociolek, in Q.Liu et al. 2014a
Neidium angustatum Q.Liu, Q-X.Wang & Kociolek in Q.Liu et al. 2017
Neidium apiculatooides Q.Liu, Q-X.Wang & Kociolek in Q.Liu et al. 2017
Neidium avenaceum Q.Liu, Q-X.Wang & Kociolek in Q.Liu et al. 2017
Neidium bacillum Q.Liu, Q-X.Wang & Kociolek in Q.Liu et al. 2017
*Neidium chenii* Y.Liu & Kociolek in Y.Liu et al. 2014a
*Neidium convexum* Q.Liu, Q-X.Wang & Kociolek in Q.Liu et al. 2017
*Neidium dicephalum* Q.Liu, Q.X.Wang & Kociolek in Liu et al. 2017
*Neidium hitchcockii* var. *obliquestriatum* f. *densestriatum* Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
*Neidium lacusflorum* Q.Liu, Q-X.Wang & Kociolek in Q.Liu et al. 2017
*Neidium ligulatum* Q.Liu, Q-X.Wang & Kociolek in Q.Liu et al. 2017
*Neidium limuae* Y.Liu & Kociolek in Y.Liu et al. 2014a
*Neidium qia* Q.Liu, Q-X.Wang & Kociolek in Q.Liu et al. 2017
*Neidium rostellatum* Q.Liu, Q-X.Wang & Kociolek in Q.Liu et al. 2017
*Neidium suboblongum* Q.Liu, Q-X.Wang & Kociolek in Q.Liu et al. 2017
*Neidium suoxiyuae* Y.Liu & Kociolek in Y.Liu et al. 2014a
*Neidium tibetianum* Q.Liu, Q-X.Wang & Kociolek in Q.Liu et al. 2017
*Neidium tibeticum* Y.Liu & J.P.Kociolek in Y.Liu et al. 2014a
*Neidium tortum* Q.Liu, Q-X.Wang & Kociolek in Q.Liu et al. 2017
*Neidium triundulatum* Q.Liu, Q-X.Wang & Kociolek in Q.Liu et al. 2017
*Neidium zhui* Y.Liu & J.P.Kociolek in Y.Liu et al. 2014a
*Neidium zoigeaeum* Q.Liu, Q-X.Wang & Kociolek in Q.Liu et al. 2017

*Nitzschia acuta* var. *argunensis* Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
*Nitzschia angustata* var. *dalaica* Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
*Nitzschia apiculata* var. *latostriata* Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
*Nitzschia fonticola* var. *acuta* Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
*Nitzschia gracilis* var. *minuta* Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
*Nitzschia hastata* Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
*Nitzschia hastata* var. *obtusa* Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
*Nitzschia hastata* var. *parallelistriata* Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
*Nitzschia intermedia* var. *sinica* Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
*Nitzschia kalganica* Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
*Nitzschia linearis* var. *robustrior* Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
*Nitzschia obtusa* var. *minuta* Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
*Nitzschia parvula* var. *recta* Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Nitzschia recta var. lanceolata Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Nitzschia recta var. tenuirostris Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Nitzschia sheshukowae Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Nitzschia sinuata var. undulata Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Nitzschia tryblionella f. obtusiuscula mongolica Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Nitzschia tryblionella var. tungtingiana Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Nitzschia tungtingiana Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Nitzschia wangtzianii Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Nupela major P.Yu, Q-M.You & Kociolek in Yu et al. 2017
Oricymba rhynchocephala Zhang & Kociolek in Zhang et al. 2018c
Oricymba tianmuensis Zhang & Li in Zhang et al. 2015
Oricymba xianjuensis Zhang & Kociolek in Zhang et al. 2016a
Pinnularia amurensis Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Pinnularia appendiculata var. densestriata Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Pinnularia argunensis Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Pinnularia balfouriana var. brevicostata Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Pinnularia aquaedulcis Y.Liu, Kociolek & Q-X.Wang in Kociolek et al. 2018
Pinnularia borealis var. densestriata Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Pinnularia braunii var. angustata Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Pinnularia braunii var. curta Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Pinnularia ceylonica var. costulata Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Pinnularia ceylanica var. gigantea Skvortzov, 2012 (original description)
Pinnularia composita Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Pinnularia composita var. acuta Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Pinnularia composita var. distincta Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Pinnularia composita var. linearis Skvortzov ex Gololobov & Kulikovskiy in Kulikovsky et al. 2012
Pinnularia dactylus var. convergentissima Skvortzov ex Gololobov & Kulikovskiy in Kulikovsky et al. 2012
Pinnularia dactylus var. mingiana Skvortzov ex Gololobov & Kulikovskiy in Kulikovsky et al. 2012
Pinnularia dactylus var. semitropica Skvortzov ex Gololobov & Kulikovskiy in Kulikovsky et al. 2012
Pinnularia dalaica Skvortzov ex Gololobov & Kulikovskiy in Kulikovsky et al. 2012
Pinnularia clavata Y.Liu, Kociolek & Q-X.Wang in Y.Liu et al. 2018a
Pinnularia crater-lapis Y.Liu, Kociolek & Q-X.Wang in Y.Liu et al. 2018a
Pinnularia daerbinsis Y.Liu, Kociolek & Q-X.Wang in Y.Liu et al. 2018a
Pinnularia dicephala Y.Liu, Kociolek & Q-X.Wang in Y.Liu et al. 2018a
Pinnularia distans Y.Liu, Kociolek & Q-X.Wang in Y.Liu et al. 2018a
Pinnularia elliptica Y.Liu, Kociolek & Q-X.Wang in Y.Liu et al. 2018a, accepted as Pinnularia palidis Y.Liu, Kociolek & Q-X.Wang in Kociolek et al. 2018
Pinnularia episcopalis var. mingiana Skvortzov ex Gololobov & Kulikovskiy in Kulikovsky et al. 2012
Pinnularia gibba var. mingiana Skvortzov ex Gololobov & Kulikovskiy in Kulikovsky et al. 2012
Pinnularia gibba var. lata Skvortzov ex Gololobov & Kulikovskiy in Kulikovsky et al. 2012
Pinnularia gigantea Skvortzov ex Gololobov & Kulikovskiy in Kulikovsky et al. 2012
Pinnularia gigantea var. interrupta Skvortzov ex Gololobov & Kulikovskiy in Kulikovsky et al. 2012
Pinnularia gigantea var. minor Skvortzov ex Gololobov & Kulikovskiy in Kulikovsky et al. 2012
Pinnularia hartleyana var. amurensis Skvortzov ex Gololobov & Kulikovskiy in Kulikovsky et al. 2012
Pinnularia gracile Y.Liu, Kociolek & Q-X.Wang in Y.Liu et al. 2018a
Pinnularia hemiptera var. longilineata Skvortzov ex Gololobov & Kulikovskiy in Kulikovsky et al. 2012
Pinnularia interrupta var. tungtingiana Skvortzov ex Gololobov & Kulikovskiy in Kulikovsky et al. 2012
Pinnularia jao Skvortzov ex Gololobov & Kulikovskiy in Kulikovsky et al. 2012
Pinnularia kolbei Skvortzov ex Gololobov & Kulikovskiy in Kulikovsky et al. 2012
Pinnularia kraskei Skvortzov ex Gololobov & Kulikovskiy in Kulikovsky et al. 2012
Pinnularia kraskei var. latior Skvortzov ex Gololobov & Kulikovskiy in Kulikovsky et al. 2012
Pinnularia lacushankae var. convergenda Skvortzov ex Gololobov & Kulikovskiy in Kulikovsky et al. 2012
Pinnularia lata var. amurensis Skvortzov ex Gololobov & Kulikovskiy in Kulikovsky et al. 2012
Pinnularia lata var. linearis Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Pinnularia legumen var. sinica Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Pinnularia liouniata Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Pinnularia major var. sinica Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Pinnularia meisteriana Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Pinnularia montium Y.Liu, Kociolek & Q-X.Wang in Kociolek et al. 2018a
Pinnularia palidis Y.Liu, Kociolek & Q-X.Wang in Kociolek et al. 2018a
Pinnularia paliobducta Y.Liu, Kociolek & Q-X.Wang in Kociolek et al. 2018a
Pinnularia paludosa Y.Liu & Q-X.Wang, 2010 in Y.Liu et al. 2010b
Pinnularia paludosa Y.Liu & Q-X.Wang, 2010 in Y.Liu et al. 2010b
Pinnularia parallela Y.Liu, Kociolek & Q-X.Wang in Y.Liu et al. 2018a, accepted as Pinnularia shii Y.Liu, Kociolek & Q-X.Wang in Kociolek et al. 2018a
Pinnularia parvulum Y.Liu, Kociolek & Q-X.Wang in Y.Liu et al. 2018a
Pinnularia platycephala var. nipponica Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Pinnularia polyonca var. nipponica f. australis Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Pinnularia pseudosinistra Y.Liu, Kociolek & Q-X.Wang in Y.Liu et al. 2018a
Pinnularia qii Y.Liu, Kociolek & Q-X.Wang in Y.Liu et al. 2018a
Pinnularia rectangularis Y.Liu, Kociolek & Q-X.Wang in Y.Liu et al. 2018a
Pinnularia shii Y.Liu, Kociolek & Q-X.Wang in Kociolek et al. 2018a
Pinnularia sinicorum Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Pinnularia stauroptera var. mingiana Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Pinnularia stauroptera var. rostrata Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Pinnularia streptoraphe var. argunensis Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Pinnularia streptoraphe var. tumida Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Pinnularia subcapitata var. mingiana Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012
Pinnularia subdalenii Q-X.Wang & Y.Liu, 2010 in Y. Liu et al. 2010b
Pinnularia subbrebissonii Y.Liu, Kociolek & Q-X.Wang in Y.Liu et al. 2018a
Pinnularia submicrostauron Y.Liu, Kociolek & Q-X.Wang in Y.Liu et al. 2018a, accepted as Pinnularia aquaedulcis Y.Liu, Kociolek & Q-X.Wang in Kociolek et al. 2018
Pinnularia subnotabilis Y.Liu, Kociolek & Q-X.Wang in Y.Liu et al. 2018a
Pinnularia subobscura Y.Liu, Kociolek & Q-X.Wang in Y.Liu et al. 2018a
Pinnularia subsalaris var. sinica Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012

Pinnularia tabellaria var. sinica Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012

Pinnularia tschangbaishanica Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012


Pinnularia wuyiensis Zhang et al. 2016

Pinnularia xianhensis Y.Liu, Kociolek & Q.X.Wang in Y.Liu et al. 2018a

Pinnularia zebra Y.Liu, Kociolek & Q.X.Wang in Y.Liu et al. 2018a

Placoneis sinensis Y.Li & D.Metzeltin in Gong et al. 2013

Platessa guangzhouae Y.Liu & Kociolek in Y.Liu et al. 2014b

Pliocaenicus changbaiense Stachura-Suchoples and Jahn 2009

Prestauroneis lowei Liu, Wang & Kociolek, 2014

Prestauroneis nenwai Liu, Wang & Kociolek, 2014

Psammothidium hainanii Kociolek & Y.Liu, in Liu et al. 2014

Rhopalodia gibba var. dalaica Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012

Rhopalodia pseudogibba Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012

Rhopalodia pseudogibba var. arcuata Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012

Rhopalodia pseudogibba var. pseudoventricosa Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012

Stauroneis javanica var. truncata Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012

Stenopterobia recta Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012

Stephanodiscus argunensis Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012

Stephanodiscus argunensis var. simple Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012

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*Synedra chungii* Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012

*Synedra sinica* Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012

*Synedra sinica var. recta* Skvortzov ex Gololobov & Kulikovskiy in Kulikovskiy et al. 2012

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*Ulnaria wulingensis* B.Liu in B.Liu et al. 2019a


The rediscovery of *Uraria lacei* Craib (Leguminosae) after 67 years from India

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Abstract

Manipur is one of the biodiversity-rich states in the North-Eastern region of India, and it is also part of the Indo-Burma biodiversity hotspot with rich plant diversity and endemism. Recent field exploration in the area has resulted in the rediscovery of *Uraria lacei* Craib after 67 years from its last collection in 1952. The rediscovery of this beautiful species fills a gap in the current distribution knowledge and should pave the way for its immediate conservation and propagation.

Keywords

Biodiversity hotspot, Fabaceae, Manipur, rediscovery, *Uraria*

Introduction

The genus *Uraria* Desv. (Fabaceae-Papilionoideae-Desmodieae) contains about 20 species distributed in tropical Africa, South East Asia and Australia (Ohashi et al. 2006). In India, the genus has eight to 12 species predominantly found in tropical and sub-tropical regions (Baker 1879, Sanjappa 1992, Gaur 1999, Kirtikar and Basu 2001). *Uraria lacei* Craib is a beautiful species with dark blue inflorescence and is distributed in India, China, Laos, Myanmar, Thailand and Vietnam. The
panicle of *U. lacei* is similar to that of *U. oblonga* (Wall. ex Benth.) H. Ohashi & K. Ohashi (Ohashi et al. 2018). In India, *U. lacei* is reported from the states of Nagaland, Manipur, Mizoram and Bihar (Sanjappa 1992). However, published literature and herbarium data suggests that, although the species was mentioned in the recent floras of Manipur (Singh et al. 2000) and Mizoram (Singh et al. 2002), these records were based on older collections. During a field study in November 2019 by the first author to North East India, the species was collected in flowering and fruiting stages from a hillslope at the only floating National Park (Keibul Lamjao National Park, Bishnupur, Manipur) in the world. After compiling all the data available in the public domain and specimens in different herbaria, it was observed that the last collection was from 11 September 1952 (*D.B. Deb 585, CAL*). In the past 67 years, the species was not recollected from its occurrence in India, therefore, this certainly raises questions about its current status, conservation and existence in nature. Detailed description, taxonomic notes and colour photographs of *U. lacei* are provided here.

**Methods**

All the published literature were scrutinized for the probable localities or distribution of *Uraria* spp. in India. With that distribution data, a field survey was conducted during October–November 2019 in the states of Assam, Nagaland, Manipur and Meghalaya of India to collect plants of *Uraria* spp. Fresh specimens of *U. lacei* were collected in flowering and fruiting stages from Manipur. The flowering twigs were packed in airtight polybags, flowers and fruits were separately collected in collection tubes containing 70% ethanol for further studies. Field notes recorded included habit, habitat, number of individuals in the population, geo-coordinates, and elevation data. In transit camp, the specimens were pressed and dried on blotting sheets. Upon reaching the institute, they were processed in the herbarium following standard herbarium procedures (Jain and Rao 1977). All the collected samples were dissected and were examined under stereo microscope (LEICA S8 APO, Wetzler, Germany) and described. Taxonomic literature and protologues were studied and compared for identification (Hasskarl 1844; Clarke 1889; Lecomte 1920; Haines 1921; Deb 1961; Thuan et al. 1987; Sanjappa 1992; Sha 1994; Singh et al. 2000; Singh et al. 2002; Kumar and Sane 2003; Ohashi et al. 2006; Puhua et al. 2010).

Herbarium sheets were consulted which are available in GBIF as well as various Indian (AHMA, ARUN, APF, ASSAM, BSA, BSD, BSI, BSID, CAL, DD, FRC, LWG, MH and TBGT) and foreign digital herbaria (A, B, BM, BO, E, H, K, L, MO, NY, P and US) (acronym following Thiers 2018). The specimens of *U. lacei* were found in DD, CAL, K, P, E, MO, L, A and US. The collected voucher specimens have been deposited at LWG. The distribution map was prepared using QGIS 3.8.0- Zanzibar.
Rediscovery of *Uraria lacei* Craib

**Taxonomy**


Figs 1, 2


**Description.** Shrubs up to 3 m height. Roots taproot with lateral roots. Stems erect, solid, strong, striate, 0.5–0.9 cm wide with ferruginous hooked hairs (0.018–0.099 cm long) and straight hairs (0.008–0.045 cm long), internodes 0.7–3.0 cm long. Leaves trifoliolate, rarely 4-foliolate, 8.0–21.5 × 7–17 cm; petiole terete, 1.5–5.0 × 0.2 cm, scabrous, up to 0.1 cm long hairs; rachis 1.0–2.5 × 0.1–0.2 cm; petiolule densely scabrous, 0.2–0.4 cm long; terminal leaflets 3.7–13.2 × 2.1–7.5 cm, lateral leaflets smaller than terminal, 4.0–10.5 × 1.4–4.1 cm, leaflets elongated ovate, obtuse at both ends, margin entire to crenate, apex mucronate; lateral veins 9–14 pairs, up to margin, with dense

![Figure 1. Map of Manipur showing the locality where *Uraria lacei* was rediscovered.](image-url)
Figure 2. The first photographs of *Uraria lacei* Craib A habitat B habit C young panicle D mature panicle E stipules and magnified stem hairs F leaflets G upper surface of leaf H lower surface of leaf I abaxial surface of bract J adaxial surface of bract K rachis and fruit position with magnified hairs of pedicel L flower position on the panicle M single flower N calyx (Safranin stained) O petals–standard, wings, keel (Safranin stained) P androecium with magnified anthers (Safranin stained) Q gynoecium with magnified hairs R single pod S single seed. Scale bars: 2 mm (J, N–Q); 500 µm (S).
brown hairs underneath; midrib protruding underneath, with both dense long straight and hooked brown hairs; leaf blade adaxial (upper) surface pilose with both eglandular straight and hooked hairs, few scattered glandular straight hairs, blade with granular deposition; leaf blade abaxial (lower) surface tomentose soft hairs, shines white in sunlight. Stipules 2, not covering whole of stem width, triangular, caudate, 0.9–1.5 × 0.3–0.6 cm with scabrous hooked and straight hairs; stipels elongated triangular, 0.3–0.5 cm long with scattered scabrous hairs. Inflorescence a very lax panicle, 17–40 × 6–24 cm, ferruginous hairy, young panicle with many bracts and short secondary rachis, mature panicle with deciduous bracts and longer secondary rachis, panicle terminal, sometimes axillary; secondary rachis green, with yellowish-white glandular hairs and short hooked brown hairs; flowers in pairs; pedicels 0.8–1.0 cm long, violet-purple, minutely bent towards calyx, with short hooked white hairs (0.017 cm long). Calyx valvate, 0.3–0.5 cm long, violet-purple, sepals 5, persistent, upper two lobes completely joined together except slightly at the tooth, lower three free at teeth, joined at tube, both lobes almost of equal length, lobes abaxially glandular hairy. Corolla dark blue, petals 5, standard suborbicular, 0.87–0.88 × 0.97–1.02 cm, with two white spots adaxially towards base; wings dark blue, purple, towards base white, 0.81–0.86 × 0.38–0.48 cm, auricle slightly drooped, up to 0.12 cm long; keel-petals 0.99–1.04 × 0.44–0.51 cm, auricle minute, up to 0.04 cm long. Androecium 9 + 1, filament 1.04–1.08 cm long, filament sheath 0.83–0.88 cm × 0.14–0.15 cm, filament tips 0.05–0.14 cm long; anthers 0.07–0.08 × 0.04–0.06 cm. Gynoecium 1.15–1.27 × 0.05 cm, ovary 0.51–0.55 cm long, with 4–8 ovules, slightly appressed hairy, style ca. 0.62 cm long, bent. Pods coiled, 4–8 articles, 0.7–1.2 × 0.3–0.4 cm, green to brownish, with long glandular hairs (0.03–0.06 cm) and minute eglandular hooked (0.008–0.019 cm long) hairs on the joints; seeds yellowish, 0.23–0.25 × 0.18–0.20 cm.

**Phenology.** Flowering from October to November, fruiting from November to December.

**Specimens examined.** China. Yunnan: No locality, No altitude, 1897, A. Henry 9144 (CAL); Szemoa, A. Henry 9144A (US02055945); Mengtze, A. Henry 9144C (MO-2331548, A00234907, A00234912); A. Henry 9144 (US-02055943, 02055944); Puerh, A. Henry 9144C (K000858912); Southern Yunnan, Between Muang Hai and Keng Hung, 15–17 Feb 1922, J.F. Rock 2492a (US-02055941); West of Talifu, Mekong watershed, en route to Youngchang and Tengyueh, Sept.-Oct. 1922, J.F. Rock 6615, 6585 (US-02055940, 02055942); India. Manipur: Manipur, Laimatak, 3–4000 ft, Nov 1907, A. Meebold 6245 (CAL); Myring Naga Hills, 5000 ft, Dec 1907, A. Meebold 9263 (CAL); Litan, 3000 ft, 12 Nov 1944, N.L. Bor 18132 (CAL); Palel, 3000 ft, 13 Nov 1945, A.H. Bullock 793 (L0477544); Karong, 3500 ft, 26 Sept 1950, Walter N. Koelz 26287 (L0477545); Imphal, 11 Sept 1952, D.B. Deb 585 (CAL); Bishnupur district, Keibul Lamjao National Park, 24.475687°N, 93.814391°E, 773 m, 17 Nov 2019, Jahnabi Gogoi 327778, 327779 (LWG-106051, 106052, 106050, 106053); 24.475614°N, 93.814607°E, 758 m, Jahnabi Gogoi 327780 (LWG-106054, 106054); 24.475590°N, 93.814555°E, 755 m, Jahnabi Gogoi 327781 (LWG-106056); Nagaland: Kohima, 3000 ft, 19 Oct 1885, C.B. Clarke 40924; S.N. Bal 513 (CAL); Naga Hills, Assam, 1935, N.L. Bor 32 (DD); Myanmar. Maymyo Plateau, 3500 ft, 31 Oct 1911,
J.H. Lace 5512 (DD, E00899264); Maymyo plateau, 3500 ft, 5 Oct 1912, J.H. Lace 4325/5512? (E00899265); Shwebo District, Kanza Laga Reserve, near Maukaw Forest Rest House, under 1000 ft, 16 Nov 1917, C. Gilbert Rogers 670 (CAL, DD); Myit Kyina District, Ka dw nan Pa law, 9 Nov 1930, Maung Ba Pe 11834 (CAL, DD); Vietnam: Plateau de kiendi, dans les paturges, 7 Oct 1891, B. Balansa 4430 (P02142551); N. du Tonkin, 900 m, 31 Dec 1937, M. Poilane 26958 (P02996196, P03089173).

Conservation status. Based on the available literature in the public domain, and our recent field studies, we suggest that *U. lacei* can be provisionally considered under the ‘Data deficient’ category of IUCN (IUCN 2019). However, a further assessment of the threat operating on the species in question needs to be done as per IUCN guidelines.

Discussion

*Uraria lacei* was first collected by C.B. Clarke on 19 Oct 1885 from Kohima, Nagaland, India. He published the novelty as *U. paniculata* C.B. Clarke in 1890, but was unaware of the fact that the same name exists for a different type *U. paniculata* Hassk. in 1844, thus making it as a later homonym. Gagnepain, in 1920, realised this and renamed it *U. clarkei* Gagnepain, giving credit to C.B. Clarke. In the meantime, Craib (1910) already published it as *U. lacei* Craib, thereby it became the accepted name with priority. *Uraria lacei* was named after the collector of the type specimen, John Henry Lace, a famous botanist and forester in India, Myanmar, Pakistan, etc. His collection period was from 1889 to 1912. There are many species named after him including *Styrax lacei* W.W. Smith (Styracaceae), *Parastyrax lacei* (W. W. Smith) W. W. Smith (Styracaceae), *Derris lacei* Dunn (Fabaceae), and *Euphorbia lacei* Craib (Euphorbiaceae).

*Uraria lacei* is completely different from other species of *Uraria* in its inflorescence. Although the panicle resembles *U. oblonga* (Wall. Ex Benth.) H. Ohashi & K. Ohashi, it differs in having trifoliolate leaves rather than the unifoliolate leaves of the latter. The field observation revealed that the rediscovered population had about 20 individual plants within 2 m² area on the slope of a small hill at Keibul Lamjao National Park, Bishnupur. There were both young saplings as well as mature 2–3 m tall plants. Most of the plants were in flowering and fruiting condition. The soil was sliding due to clearance for road and mostly consisted of small pieces of rocks. The plants were growing with grasses and pines.

While going through the protologue and various literature, it was observed that the species is uniformly described to have terminal inflorescence. However, we observed both terminal as well as axillary panicle during the field survey (Fig 3). The protologue also suggested the pods to be “fere glabrum” (i.e. almost smooth), which can also mean there might be scarce minute hairs that are not noticeable. On the plants that we collected, the glandular hairs were clearly visible with naked eyes, but were not very dense. Unlike the dense glandular haired pedicel described by Ohashi et al. 2006 from China, the specimens collected were observed to have minute hooked hairs on its pedicels. Thuan et al. (1987) described the calyx as glabrous while Ohashi et al. (2006) described the calyx as densely glandular hairy. Our specimens were neither glabrous
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nor densely glandular hairy, but were scarcely glandular hairy. As observed in the field, the plants rarely have 4-foliolate leaflets (Fig 3).

As the plant has beautiful inflorescence and foliage, it would therefore be well-suited for domestication as an ornamental plant. Keibul Lamjao National Park, Manipur (India) is itself a protected area but anthropogenic activities like tourism is allowed in the buffer zone, therefore the vulnerability of *U. lacei* still cannot be ruled out. We could not locate any other population nearby to the present location and, given its rarity, there is an urgent need to conserve the population of this species in its present locale. Furthermore, species specific habitats need to be identified using ecological niche modelling (ENM) tools and saplings multiplied using both macro as well micro-propagation techniques, should be planted in the specific habitats to ensure the in-situ conservation of the species.

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References


Rediscovery of *Uraria lacei* Craib


A new record of critically endangered *Saussurea bogedaensis* (Asteraceae) from Dzungarian Gobi, Mongolia

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**Abstract**

A species in the family Asteraceae, *Saussurea bogedaensis*, was newly described from Bogeda Mountain in Xinjiang, China and is a critically endangered species in China. Morphological and genetic characteristics confirm the presence of this species in Mongolia, as it was found in Baitag Bogd Mountain (in the Dzungarian Gobi). In addition, the distribution and conservation status of *S. bogedaensis* are provided.

**Keywords**

Asteraceae, conservation status, distribution, Mongolia, *Saussurea*

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**Introduction**

*Saussurea* DC. is one of the largest genera in the tribe Cardueae (Asteraceae) and comprises ~500 species, classified into six subgenera and 20 sections (Lipschitz 1979; Raab-Straube 2017). The genus is distributed throughout the Northern Hemisphere, with diverse species in Central Asia (Wang et al. 2009). *Saussurea* spp. occur in a wide range of habitats, especially at higher altitudes with cold and dry conditions, but they also grow in lowlands. However, *Saussurea* spp. have a tendency towards habitat specificity (Butola...
and Samant 2010). The highest number of *Saussurea* spp. is reported from China, with estimated 317 species (Chen and Yuan 2015). Sixty-one species are noted as native to India (Hajra 2000; Ahmad 2005), 54 species are mentioned in the flora of Siberia (Shurupova and Zverev 2017), 41 indigenous species are listed in the flora of Bhutan (Grierson and Springate 2001) and 23 species have been recorded in Pakistan (Ahmad 2005). To date, 53 species of *Saussurea* have been recorded in Mongolia (Gubanov 1996; Urgamal et al. 2014; Dariimaa 2017). Amongst these, five species, namely *S. catharinae* Lipsch., *S. gubanovii* Kamelin, *S. klementzii* Lipsch., *S. ramosa* Lipsch. and *S. saichanensis* Komarov ex Lipsch. are endemic to Mongolia (Urgamal and Oyuntsetseg 2017).

*Saussurea* is known for its wide array of uses, especially for medicinal and religious purposes (Mishra et al. 2018; Qureshi et al. 2018; Semwal and Painuli 2019). Additionally, the essential oils of several species are used in high-grade perfumes and as insecticides (Butola and Samant 2010). As a result of having a number of medicinal properties and economic uses, several *Saussurea* species are becoming threatened or endangered owing to over-exploitation and degradation of their habitats (Kamalpreet et al. 2019), as well as their natural rarity and small population size. These valued species include *S. involucrata* (Kar. & Kir.) Sch.Bip. and *S. orgaadayi* Khanm & Krasnob. which are listed as endangered species in the conservation list of Mongolia (Oyuntsetseg et al. 2018).

Our study initially aimed to clarify the taxonomic relationship between *S. involucrata* and *S. orgaadayi* in Mongolia and to assess the conservation status of these species. These two species are classified as endangered at the regional level and occur only in the western part of Mongolia (Grubov 1982; Gubanov 1996; Urgamal et al. 2014; Dariimaa 2017). Furthermore, both species have some morphological similarities, leading to misidentifications. Regarding their distribution range, *S. involucrata* is noted in four phytogeographical regions in western Mongolia: Mongolian Altai (MA), Dzungarian Gobi (DzG), Khovd and the Depression of Great Lakes (Grubov 1982; Dariimaa 2017). *Saussurea orgaadayi* is only noted in the MA region (Urgamal et al. 2014; Oyuntsetseg et al. 2017). *Saussurea involucrata* and *S. orgaadayi* belong to the *Saussurea* subg. *Amphilaena*, known for its taxonomic complexity (Raab-Straube 2017). However, *S. orgaadayi* can be differentiated from *S. involucrata* based on morphological characteristics of the capitula (Shi and Raab-Straube 2011; Raab-Straube 2017).

Recently, Chen and Wang (2018) discovered a new *Saussurea* species from Bogeda Mountain (Mt) in Xinjiang, China and named it *S. bogedaensis* Yu J.Wang & J.Chen. This newly-described species is closely related to *S. involucrata* and *S. orgaadayi*. This species had also been misidentified owing to its morphological similarity to *S. involucrata* and *S. orgaadayi*. Due to this confusion, Chen and Wang (2018) comprehensively investigated all three species and revealed some differences in their morphological characteristics, geographical distribution and phylogenetic positions. They also noted that *S. orgaadayi* was recorded in the Altai Mountains (Mts), and *S. involucrata* in the western part of the Chinese Tien-Shan Mts (Shi and Raab-Straube 2011; Chen and Wang 2018). *Saussurea involucrata* has been known to occur both in the DzG and MA regions of Mongolia (Urgamal et al. 2014). However, based on the distribution range indications of Chen and Wang (2018), the species recorded in the Mongolian
Saussurea bogedaensis is new to Mongolia. Thus, inconsistencies in the distribution range of these three Saussurea species, which could have been misidentified in Mongolia as well, motivated us to conduct an in-depth taxonomic assessment. In addition, Chen et al. (2019) recommended the use of nuclear ribosomal (nr) DNA ITS and chloroplast (cp) DNA regions of rbcL and trnH-psbA as candidate DNA barcode markers for species in the subg. Amphilaena. Using these three markers, it was possible to discriminate the Saussurea species that are morphologically similar and separated very recently.

The main objectives of the present study were to (1) re-identify the above mentioned Saussurea species recorded in western Mongolia and (2) newly report S. bogedaensis and describe its distribution and conservation status in the Mongolian flora.

Materials and methods

Herbarium and field research

The basic distribution data and photographs of the target Saussurea species, which had been known as S. involucrata and S. orgaadayi in Mongolia, were collected during our fieldwork from 2013 to 2019 in western Mongolia. We also included herbarium materials kept at UBA, UBU, OSBU and MW (abbreviations are according to Thiers 2019+).

DNA barcoding

In this study, we investigated the application of combined nrDNA region of ITS and cpDNA regions of trnK, trnH-psbA and rbcL in barcoding analyses of two Mongolian Saussurea species. Additionally, a total of 36 sequences, based on four markers of three species (S. bogedaensis, S. orgaadayi and S. involucrata), which were used by Chen and Wang (2018) to evaluate the phylogenetic relationships between these species, were obtained from NCBI GenBank (Table 1). Jurinea multiflora (L.) B.Fedtsch. was selected as an outgroup based on Chen and Wang (2018) and Chen et al. (2019). Detailed information on sample collection, voucher specimens, Genbank accession numbers and references of each sample is provided in Table 1.

Total genomic DNA was extracted from silica gel-dried leaf materials following the CTAB method (Doyle and Doyle 1987). The PCR reaction was performed in a 50 µl volume, containing approximately 200 ng DNA, 1.5 mM MgCl$_2$, 0.2 mM dNTP, 1 µM of each primer and 0.75 units of Taq DNA polymerase. Initial template denaturation was programmed at 94 °C for 4 min and then followed by 30 cycles of 94 °C for 1 min, annealing at 50–56 °C for 1 min and extension at 72 °C for 1 min, with a final extension step of 72 °C for 7 min. Markers used for the amplification and sequencing are listed in Table 2. PCR products were sent to ZanaaSPX, Mongolia (www.hangal.mn) for commercial sequencing. Sequences were aligned using MEGA 7 (Kumar et al. 2016), with the default settings and
manual adjustments were made using SnapGene Viewer 4.2.6. Sequences were edited manually using SnapGene Sequence Alignment Editor (GSL Biotech LLC). Ambiguous nucleotide bases were corrected using the corresponding base of the sequence that was obtained by the reverse primer. Multiple sequences were aligned using ClustalW with its default parameters (Thompson et al. 1994) and consensus sequences were created for each species. For the combined dataset, the genetic

**Table 1.** Detailed information on taxa, sampled locations, voucher specimens, NCBI GenBank accession numbers and references of the samples used in this study.

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Location &amp; Herbarium accession number</th>
<th>Latitude (N) / Longitude (E)</th>
<th>Altitude (m)</th>
<th>GenBank accession number</th>
<th>Reference</th>
</tr>
</thead>
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<td>MT209829</td>
<td>This study</td>
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<td>MT210906</td>
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<td>MT210907</td>
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<td><strong>S. orgaadayi</strong></td>
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<td>MH003775</td>
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**Table 2.** List of the markers used for the DNA barcoding and phylogenetic analysis.

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<th>Fragment</th>
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<th>T&lt;sub&gt;s&lt;/sub&gt;</th>
<th>Reference</th>
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<td>ITS</td>
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<td>50 °C</td>
<td>White et al. (1990)</td>
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<tr>
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<td>ITS5A</td>
<td>TCCTCCGCTTATTGATATGC</td>
<td>50 °C</td>
<td>White et al. (1990)</td>
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<td>rbcL</td>
<td>rbcL_f</td>
<td>ATGTCACCAACACAGAGAC</td>
<td>56 °C</td>
<td>Chase et al. (1993)</td>
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<tr>
<td></td>
<td>rbcL_r</td>
<td>ATGTCACCAACACAGAGAC</td>
<td>56 °C</td>
<td>Chase et al. (1993)</td>
</tr>
<tr>
<td>trnK</td>
<td>trnK(UUU)</td>
<td>TTTTATGATTGATATCC</td>
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<tr>
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<td>rpl16</td>
<td>AAAGTGGGTTTTTATGATCC</td>
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<tr>
<td>trnH-psbA</td>
<td>psbA</td>
<td>GTTATGCTGAGGCTATTGCT</td>
<td>56 °C</td>
<td>Olmstead et al. (1992)</td>
</tr>
<tr>
<td>trnH</td>
<td>trnH</td>
<td>CGGCATGTGGGGTACATTCC</td>
<td>56 °C</td>
<td>Olmstead et al. (1992)</td>
</tr>
</tbody>
</table>
Saussurea bogedaensis is new to Mongolia

divergences were calculated using DNASP v.6 (Julio et al. 2017) and used to determine whether a barcoding gap was present. The DNA sequences generated in this study have been deposited in GenBank (Table 1).

The phylogenetic analyses were conducted using Bayesian Inference (BI), Maximum Likelihood (ML) and Maximum Parsimony (MP). For BI analysis, the best close fit model of evolution for each partition neighbour joining (NJ) tree was estimated using MEGA 7 (Kumar et al. 2016). Posterior probability was determined by Markov Chain Monte Carlo sampling (MCMC) with the programme MrBayes v. 3.2.6 (Huelsenberk and Ronquist 2001; Ronquist and Huelsenberk 2003), as implemented in Geneious v. 10.2.2 (Kearse et al. 2012), using the estimated models of evolution. For each dataset, four simulation Markov chains were run for 1 million generations and trees were sampled every 100th generation. The ML analysis was performed using RAxML v. 8.2.11 (Stamatakis 2006, 2014) as implemented in Geneious v. 10.2.2 (Kearse et al. 2012), using the GTRGAMMA model with rapid bootstrapping and a search for the best-scoring ML tree algorithm, including 1,000 bootstrap replicates. The MP analyses were performed with MEGA 7 (Kumar et al. 2016), using tree-bisection-reconnection (TBR) as the branch-swapping algorithm. The robustness of the tree was evaluated using 1,000 bootstrap replication indices and the consistency index, retention index and composite index were calculated.

**Results**

We discovered S. bogedaensis from Baitag Bogd Mt in the DzG region of Mongolia. This species is newly documented in the Mongolian flora. Detailed data on morphological and genetic identification, geographical distribution and conservation status of the S. bogedaensis are provided below.

**New record**

Figs 1, 3

**Morphological identification.** *Saussurea bogedaensis* (Fig. 1) was recently discovered on Bogeda Mt in Xinjiang, China by Chen and Wang (2018) (Fig. 3). This species is very similar to *S. involucrata* and *S. orgaadayi* (Fig. 2), but several morphological characteristics of the bracts, involucres and phyllaries differentiate them (Chen and Wang 2018). In particular, *S. bogedaensis* differs by having elliptic, apically obtuse stem leaves (Fig. 1C) vs. lanceolate, long-acuminate stem leaves in *S. orgaadayi* (Fig. 2A); dirty white pappus colour (Fig. 1D) vs. straw-coloured pappi in *S. orgaadayi* (Fig. 2D); densely pubescent phyllaries (Fig. 1E) vs. glabrous phyllaries in *S. involucrata*; and campanulate involucres in *S. bogedaensis* vs. hemispherical involucres in *S. involucrata*. 
Genetic identification. The combined sequence dataset consisted of 15 samples, including the outgroup, *Jurinea multiflora*. The sequence dataset comprised 2,315 characteristics, of which 20 were parsimony-informative, 108 were variable and 2,169 were constant. The gene boundaries on the ITS – *trnK* – *trnH-psbA* – *rbcL* multi-locus alignment were as follows: ITS: 1–656, *trnK*: 657–1,284, *trnH-psbA*: 1,285–1,680 and *rbcL*: 1,681–2,315. The final ML optimisation likelihood of ML analysis was: Inl = -3650.7353. A single most parsimonious tree was generated by MP analysis with a tree length of 105 steps, consistency index: 1.0, retention index: 1.0 and composite index: 1.0. The BI phylogeny, including BI posterior probability values, as well as ML and MP bootstrap support values, are provided in Fig. 4.

**Figure 1.** *Saussurea bogedaensis* in Buduun Khargait river, Baitag Bogd Mt, Uyench sum, Khovd Province, Mongolia. A general habit in Baitag Bogd Mt, DzG region B fruiting C leaves D pappus E phyllaries. Photos: 28 July 2019, Sh. Baasanmunkh.
Saussurea bogedaensis is new to Mongolia.

Our genetic identification revealed a similar topology to that of Chen and Wang (2018) and confirms each distinct clade of *S. bogedaensis*, *S. involucrata* and *S. orgaadayi*, respectively (Fig. 4). Three individuals of newly-revealed Saussurea specimens from Baitag Bogd Mt formed one cluster with the Chinese *S. bogedaensis* with high support: BI/ML/MP = 1/100/99. Additionally, sequence divergence amongst the three species was 0–0.002% in our *S. bogedaensis* specimens, whereas there was 3.02% sequence divergence in *S. involucrata* and 2.04% sequence divergence in *S. orgaadayi*. Sequence alignment revealed that the Mongolian and Chinese *S. bogedaensis* share several specific nucleotide residues that are different from those of other *Saussurea* species (Fig. 5). The other three samples (Fig. 2) from Munkhkhairkhan Mt in the MA region...
clustered with *S. orgaadayi* from China (BI/ML/MP = 1/100/99). Therefore, our study proves that the *Saussurea* samples from the DzG and MA regions are *S. bogedaensis* (Fig. 1) and *S. orgaadayi* (Fig. 2), respectively. Our genetic results provide only the genetic differences between the three related species in the subg. *Amphilaena* and not a true phylogeny of all related *Saussurea* species.

**General distribution and habitat.** Mongolia (Dzungarian Gobi, Baitag Bogd Mt) and China (Xinjiang, Bogeda Mt). In Mongolia, *S. bogedaensis* grows on high mountain rocky slopes, scree, boulders and river banks in the alpine belt at altitudes of 2400–3300 m a.s.l. This species is closely related to *S. involucrata* and *S. orgaadayi*. However, the three species are geographically isolated: *S. bogedaensis* occurs in the Dzungarian basin and the eastern Chinese Tien-Shan Mts and *S. involucrata* occurs in the Tien-Shan Mts (which cover parts of China and Central Asian states), whereas *S. orgaadayi* is present in the Altai Mts (which cover parts of China, Mongolia and Russia) (Fig. 3), according to Raab-Straube (2017) and Chen and Wang (2018).

**Conservation status.** *Saussurea bogedaensis* is new to the Mongolian flora and occurs in the Baitag Bogd Mt in the DzG region. Individuals of the species were found in a few
Saussurea bogedaensis is new to Mongolia

Figure 4. Phylogenetic tree based on concatenated sequence alignments of nrDNA (ITS) and cpDNA (trnK, trnH-psbA, and rbcL) regions. Bayesian Inference (BI) posterior probability support values above 90% (bold), Maximum Likelihood (ML) and Maximum Parsimony (MP) bootstrap support values above 70% are shown in the branches in the following order BI/ML/MP. The new samples of $S. \text{bogedaensis}$ and $S. \text{orgaadayi}$ originated from Mongolia are in red and black bolds, respectively.

locations, namely in Baitag Bogd Mt and Altan Ovoo in the DzG region (Fig. 3). During our field surveys, we detected two different populations, which in total, accounted for fewer than 600 individuals in this region. This species is under threat, particularly owing to human interference and random cutting. Thus, $S. \text{bogedaensis}$ has been assessed as Critically Endangered [CR C2a(i)] in Mongolia according to the IUCN Red List categories and criteria (IUCN 2019). This species was also evaluated as critically endangered in China (Chen and Wang 2018). In situ studies on the reproductive biology of $S. \text{bogedaensis}$ are needed to more accurately assess the conservation status of this species in Mongolia.

**Specimens examined (new record).** MONGOLIA. Dzungarian Gobi region: Khovd Province, Uyenchn sum, Baitag Bogd Mt, Budun Khargait river, 45°13'13.52"N, 90°55'12.97"E, 2742 m a.s.l., 28 Jul 2019, $Sb. \text{Baasanmunkh et al., 20190698, 20190699, 20190700}$ (UBU). The samples from this site were used for the molecular analysis confirming the identity of the Mongolian plants as $S. \text{bogedaensis}$. 

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**Figure 4.** Phylogenetic tree based on concatenated sequence alignments of nrDNA (ITS) and cpDNA (trnK, trnH-psbA, and rbcL) regions. Bayesian Inference (BI) posterior probability support values above 90% (bold), Maximum Likelihood (ML) and Maximum Parsimony (MP) bootstrap support values above 70% are shown in the branches in the following order BI/ML/MP. The new samples of $S. \text{bogedaensis}$ and $S. \text{orgaadayi}$ originated from Mongolia are in red and black bolds, respectively.
Discussion

*Saussurea bogedaensis*, *S. orgaadayi* and *S. involucrata* belong to the taxonomically complicated *Saussurea* subg. *Amphilaena* (Raab-Straube 2017). Despite their similar morphological characteristics and habitats, there are clear morphological differences, geographically isolated distributions and genetic identities that make these species recognisable with an in-depth investigation (Figs 1–5; Chen and Wang 2018; Chen et al. 2019). There are some distribution records of *S. involucrata* from the regions of Khovd and the Depression of Great Lake in Mongolia (Urgamal et al. 2014). Due to limited numbers of samples and surveyed areas of the MA and DzG regions in this study, data on Mongolian *S. involucrata* are still unclear. Hence, correct identification based on this study will provide an important basis for future studies on the taxonomic identity of Mongolian *S. involucrata*.

Acknowledgements

Our study is supported by a research project (A survey on the vascular flora of Mongolia; Grant Number KNA 1-2-38, 20-5) of the Korean National Arboretum, South Korea and partly supported by the National University of Mongolia’s “Seed Grant”. We are grateful to Dr. Steffen Bien (Senckenberg Museum of National History Görlitz, Germany) for his help with phylogenetic analysis. We also thank to Ms. Joscie Norris (University of Vermont, Burlington, United States) for her help with

Figure 5. Multiple sequence alignment of combined nr DNA (ITS) and cpDNA (*trnK, trnH-psbA* and *rbcL*) sequences. ITS region shows more differences than cpDNA regions amongst those closely related species. (*) – no differences found between species.
improving the English writing of manuscript. Finally, the authors thank Dr. Yu-Jin Wang (Lanzhou University, China) for his careful review with valuable suggestions and personal discussion on the first draft.

References


Saussurea bogedaensis is new to Mongolia


A new taxon within *Biscutella laevigata* L. (Brassicaceae) endemic to calamine areas in southern Poland

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Abstract

A new taxon *Biscutella laevigata* subsp. *woycickii* (Brassicaceae) is described from southern Poland. The taxon is similar to *B. laevigata* subsp. *gracilis*, but differs in having thin, light-green rosette leaves very densely covered by simple non-glandular trichomes, smaller seeds and the ability to tolerate and accumulate high amounts of heavy metals. This new taxon is supported by results of cultivation experiments, as well as genetic and paleobotanical evidence.

Keywords

Biscutella, Biscutella laevigata subsp. *woycickii*, Brassicaceae, new subspecies, southern Poland, taxonomy

Introduction

Heavy-metal-rich calamine soils have been attracting human attention for several thousand years. Initially, the total area occupied by these environments was limited to small, isolated outcrops of ore-bearing rocks. Usually these areas were easy to spot due to unique vegetation covering soils that naturally developed on a metal-rich rocky...
substrate. Mining activities carried out in Europe since the Bronze Age (ca. 3 kyr BP) (Coulson 2012) contributed to a significant increase in the areas covered by calamine soils (nowadays represented mainly by mining waste heaps, riparian areas along rivers polluted by wastewater and sediments from ore-processing factories, mines etc.) and to the almost total destruction of the primary habitats of calamine vegetation (Baker et al. 2010). However, this huge, anthropogenic environmental change did not lead to the total extinction of all the plant taxa connected with calamine areas (Baker et al. 2010). On the contrary, while primary habitats of the calamine flora were destroyed, new and often more spacious environments have developed around the mining sites. Heaps of waste materials from early metal mines, which could not be easily colonised by other plants due to the very high content of zinc and lead, became ideal refugia for calamine-adapted plants.

Heavy-metal-polluted calamine soils and natural processes that resulted in the development of metal-tolerant vegetation covering such places have been at the focus of attention for many scholars since the beginning of the 20th century (Baker et al. 2010). Soon this research demonstrated that calamine areas host unique plant taxa that are often endemic. In Europe, a number of such taxa have already been formally recognised. Examples of these taxa include: *Viola calaminaria* (DC. ex Ging.) Lej., *Noccaea caerulescens* (J.Presl & C.Presl) F.K.Mey. subsp. *calaminaris* (Lej.) Holub and *Armeria alpina* Willd. subsp. *halleri* (Wallr.) Nyman.

In the vicinity of Olkusz (southern Poland), there is an old mining area with lead and zinc mining activities dating back to the 12th century (Molenda 1984). Until the end of the 20th century, open, shallow pits were used to excavate Zn-Pb ores that were located close to the ground level (Szarek-Łukaszewska et al. 2015). During the 900 years of ore exploitation, natural sites of calamine vegetation have been completely erased, but the rich and diverse calamine flora can be found in secondary habitats in the vicinity of Olkusz. Calamine grasslands occurring there on old mining waste heaps have been studied by biologists since the beginning of the 20th century (Wóycicki 1913).

In this paper, we argue that a new taxon endemic to calamine areas close to Olkusz in southern Poland deserves formal recognition at a subspecies level within *Biscutella laevigata* L.

**Materials and methods**

The study is based on field surveys, laboratory studies including experiments under controlled growing conditions, as well as on genetic analyses. Results of these studies have already been published in several papers dealing with ecology and physiology of *B. laevigata* from calamine areas. Detailed descriptions of experiments carried out by us can be found especially in papers by Wierzbicka and Pielichowska (2004) and Wasowicz et al. (2014). We also undertook an extensive review of literature and all relevant data from already published studies are also cited in our paper.
Taxonomy

*Biscutella laevigata* L. subsp. *woycickii* M.Wierzb., Pielich. & Wasowicz, subsp. nov.

**URN**: urn:lsid:ipni.org:names:77211421-1

**Figure 1**

**Type.** Poland. Olkusz, 1922, R. Kobendza, s.n. (holotype, WA0000071422 !).

**Diagnosis.** *Biscutella laevigata* subsp. *woycickii* is similar to subsp. *gracilis*, but differs from the latter in having thin, light-green rosette leaves very densely covered by simple non-glandular trichomes. Plants belonging to subsp. *woycickii* have smaller seeds and are characterised by the ability to tolerate and accumulate high quantities of heavy metals.

**Etymology.** This subspecies is dedicated to a renowned Polish botanist Zygmunt Wóycicki (1871–1941), a pioneer of biological research on calamine areas.

**Distribution and ecology.** Calamine areas in the vicinity of Olkusz, Powiat Olkuski (Olkusz County), Województwo Małopolskie (Lesser Poland Voivodeship/Province), southern Poland.

**Phenology.** Flowering in April–May, fruiting in July–August.

**Chromosome number.** A study carried out by Skalińska (1950) on plants from the calamine population in the vicinity of Olkusz resulted in the diploid chromosome number, \(2n = 18\).

**Preliminary conservation status.** Currently, the taxon is known only from calamine areas in the vicinity of Olkusz, where it is quite abundant on calamine soils. The extent of occurrence (EOO) of the taxon is 7 km\(^2\) and the area of occupancy (AOO) is 14 km\(^2\). A steady decline in population size has been observed during the last 20 years. It seems that the new taxon could be classified as Vulnerable according to the IUCN criteria (Standards IUCN 2019), but more research is needed to estimate the number of mature individuals and population dynamics.

**Discussion**

The morphological and geographic distinctiveness of *B. levigata* populations from the Olkusz Ore Bearing Region have been recognised by botanists already in the 19\(^{th}\) century (Zalewski 1886, Wóycicki 1913, Zając 1996), but the detailed morphological, anatomical and physiological studies on the problem were initiated only at the beginning of 21\(^{st}\) century. The research, carried out by us previously and already published, demonstrated that a significant amount of morphologic, physiologic and genetic differentiation exists between the isolated population of *B. laevigata* from the calamine areas near Olkusz (S Poland) and the nearest mountainous populations located in the Tatra Mountains and belonging to subsp. *gracilis*. We determined that the calamine population differs from subsp. *gracilis* in having light-green, thin rosette leaves densely covered by simple epidermal hair (Wierzbicka and Pielichowska 2004) (Fig. 2A–C). Our research has also demonstrated that the calamine morphotype has smaller seeds.
Figure 1. A holotype of *Biscutella laevigata* subsp. *woycickii* Wierzbicka, Pielichowska & Wasowicz (WA0000071422).

(as compared to subsp. *gracilis*) and shows an intense formation of daughter rosettes through vegetative reproduction (Fig. 2D). Furthermore, we identified the presence of pronounced physiological differences, including increased tolerance to Zn, Pb and Cd
A new taxon within *Biscutella laevigata*

Figure 2. Comparison of morphological characters in *Biscutella laevigata* subsp. *woycickii* subsp. nov. and *B. laevigata* subsp. *gracilis*: **A** rosette leaves **B** leaf trichomes (both images at the same scale) **C** cross-section of the leaf blade (both images at the same scale) **D** seeds.
present in the calamine population (Wierzbicka and Pielichowska 2004). Our previous research showed that this differentiation is not merely a result of phenotypic plasticity. The phenotypic differentiation was stable and preserved when plants were grown in the greenhouse under standard conditions (Wierzbicka and Pielichowska 2004) (Fig. 2). Genetic analyses, carried out using Amplified Fragment Length Polymorphisms (AFLPs), showed that a strong genetic differentiation exists between calamine populations and the nearest natural populations located in the Western Carpathians (Wasowicz et al. 2014) and there are no signs of gene flow between these two areas. No evident signs of a bottleneck effect were evidenced by AFLP (Wasowicz et al. 2014). The DW Index (Schönswetter and Tribsch 2005), measuring the genetic divergence, was high in the calamine population, suggesting their long-term isolation (Wasowicz et al. 2014).

The paleobotanical study carried out in the near vicinity clearly suggests that calamine populations in the area of Olkusz could have originated before the Last Glacial Maximum (LGM) from local, interglacial populations. The presence of the species in the region has been determined by Szafer (1930), who, during his research in Ludwinow (about 40 km SE from Olkusz), found fossil siliques of *Biscutella laevigata* dating back to the Weichselian glaciation in Northern Europe (115–11.7 kyr BP, mainly corresponding to the Würm glaciation in the Alps and the Valdai glaciation in Eastern Europe).

A recently published study, carried out on local populations in southern Poland and focused on population genetic structure using nine nuclear micro-satellite loci (Babst-Kostecka et al. 2014), fully agrees with the paleobotanical data and our AFLP results (Wasowicz et al. 2014). Babst-Kostecka et al. (2014) concluded that the local calamine population in the vicinity of Olkusz originated as a result of an old vicariance predating the Last Glacial Maximum.

All these findings have led us to propose a hypothesis that the calamine population of *B. laevigata* from Olkusz Ore Bearing Region is a descendant of an ancient relict population that, through development of a series of adaptations to heavy metal stress, colonised natural calamine areas in the vicinity of Olkusz and, subsequently (when natural calamine sites were destroyed due to mining activities), also secondary sites (Wasowicz et al. 2014). Taking the above-mentioned differences into account, we argue that the morphotype from calamine areas in the vicinity of Olkusz should be formally recognised at subspecies level.

**References**


A new taxon within *Biscutella laevigata*


A new rare and endemic species of *Sloanea* (Elaeocarpaceae) from the Chocó region of Ecuador

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Abstract

A new species collected in the lowland forests of the Chocó region of Ecuador, *Sloanea cayapensis*, is described and illustrated and its morphological similarities with other species of *Sloanea* are discussed.

Keywords

Chocó, Ecuador, endemic, lowland humid forest, *Sloanea*

Introduction

The genus *Sloanea* L. is the second largest within the family Elaeocarpaceae and comprises approximately 200 species in the tropics and more than 120 species in the Neotropics (Smith 1954; Smith 2001; Sampaio 2009). Smith (1954) proposed that the centre of diversity for this group is the northern portion of the Amazon basin, including the Guiana Shield, but the genus is as diverse in Central and Western Amazonia as in the previously mentioned region (Castañeda 1981; Boeira 2010).

The most recent taxonomic study of *Sloanea* in Ecuador revealed that 25–30 species of the genus occur in the country (Jaramillo 2003, Pennington and Wise 2017) and this number has increased with recent new descriptions (Guevara Andino et al. 2016; Guevara Andino et al. 2017). The genus is very diverse in Amazon lowland
forests and in the Chocó forests on Ecuador’s Pacific coast. As the southernmost extension of Colombia’s Chocó forests, Ecuador’s coastal Chocó is strikingly diverse (Gentry 1982) but remains poorly studied, despite several new species of the genus having been recently described (Palacios-Duque 2004a, b, 2005).

Materials and methods

We describe a new species of *Sloanea* from the Ecuadorean Chocó region, based on an analysis of morphological characters from material deposited in four Ecuadorean herbaria: the Herbario de la Pontificia Universidad Católica del Ecuador (QCA), Herbario Nacional del Ecuador (QCNE), Herbario Alfredo Paredes (QAP) and Herbario Amazónico del Ecuador (ECUAMZ). We also compared the new species with images of type specimens deposited in JStor and reviewed voucher specimens in the virtual herbaria of the Field Museum (F), the New York Botanical Garden (NY), the Herbario Nacional de Colombia (COL) and the Herbário do Instituto Nacional de Pesquisas da Amazônia (INPA); herbaria abbreviations follow Thiers 2016. In this work, we used the sub-generic classification developed by Smith (1954) for the circumscription of the new taxa. Earlier works have demonstrated that a single diagnostic character, the position of the calyx in relation to the bud, is the only consistent character in the group and may be considered diagnostic for the circumscription of taxa to the subgenus level (Sampaio 2009; Guevara Andino et al. 2016).

Taxonomic treatment

*Sloanea cayapensis* J.Jaram. & J.E. Guevara, sp. nov.

urn:lsid:ipni.org:names:77211422-1

Figs 1–4

Diagnosis. *Sloanea cayapensis* resembles *S. grandiflora* Smith and *S. fragrans* Rusby, the most morphologically similar taxa, but can be differentiated from them by having short petioles (2–7.5 cm), obovate-spatulate leaves, 6–8 free sepals, shorter thick and acute-obtuse anthers (1.5–2 mm), densely hirsute filaments and styles and by having capsules with large, flexible, curled bristles (2.8–6 cm).

Type. Ecuador. Esmeraldas: Borbón-Río Cayapas, 78°50’W, 1°5’S, 10 m elev., 3 May 2003, Jaime Jaramillo, A. Sola, S. Yandun 24200 (holotype [2 sheets]: QCA7007914! (fl, fr); QCA7007917!; isotypes QCA7007915!, QCA7007916! (fl), QCA204513!).

Medium-sized trees up to 15–18 m tall. Trunk striated, bark rough, brownish. Branchlets glabrous, quadrangular and covered by ovoid, cream-coloured lenticels. Leaves alternate; petioles 2–7.5 cm long, semi-terete, striated, shortly pubescent, thickened at the insertion with the blade; blades (18.8–42)–52(–61.8) cm long, (9.5–)17–26(–32) wide, coriaceous obovate-spatulate, attenuate-subcordate or rounded at base,
A new *Sloanea* species from Ecuadorian Chocó

obtuse-retuse at apex, the margins entire, slightly revolute; foliaceous stipules persistent at the top of the individual branchlets, 3.9–13 cm long, 2.1–3.9 cm wide, elliptical with acuminate apex, the margin entire or shallowly sinuate; primary vein prominent on the adaxial surface, very prominent and angular on the abaxial surface, secondary venation eucamptodromous, 11–20 secondary veins, prominent on the abaxial surface and ascendant (angle > 45°), flat on the adaxial surface, tertiary veins prominent on the abaxial surface, slightly flat on the adaxial surface. Inflorescence axillary, racemose; peduncles 2–6 cm long; rachis 5–18.5 cm long, slightly pubescent, deeply striated and quadrangular; pedicels 1–7 cm, stout, shortly pubescent, finely striate and quadrangular, pedicels, 1–1.5 cm long, navicular bracts at the base of individual pedicels, 4–4.5 mm long, dense appressed pubescence on both abaxial and adaxial surfaces, apex acute, commonly deciduous. Flowers with the receptacle large, expanded; sepals 6–8, free, 3–5 mm long, 2.5–3 mm wide, greenish coloured, ovate, apex acute-acuminate, margins entire, slightly involute, yellow on the outer surface, not covering the reproductive organs before anthesis. Stamens 5–6 mm long, yellow with orange anthers; filaments 3–3.5 mm long, densely hirsute, striated and angulate; anthers 1.5–2 mm long, densely hirsute, thick, the connective thin on the abaxial surface of the anther.
sacs, extended as an acute or obtuse awn, very short, up to 0.5 mm long; anther sacs not opening widely along entire length. Ovary 2–4 mm long, 1.5–2.7 wide, with four locules, 4-angled, ovoid, densely hirsute; placentation axillary; style to 8 mm long, densely hirsute at the base, becoming sparsely hirsute towards the apex. Fruits globose capsules.

Figure 2. *Sloanea cayapensis*. Image from the holotype at QCA (J. Jaramillo 24200).
1.2–2.5 cm long, 1–2 cm wide, rounded, opening by 4 rigid valves; bristles 2.8–6 cm long, curled, contorted and flexible, laterally flattened, densely hirsute at the base, more sparse and appressed pubescence towards the apex, easily detached. Seeds not studied.
Specimens examined. Paratypes. Ecuador: Esmeraldas: La Chiquita, bosque secundario, 45 m elev., Jaime Jaramillo 24422 (QCA-236170!); Esmeraldas: Localidad Borbón, entre Punta Piedra y Maldonado, 78°58’W, 1°4’S, 60 m elev., febrero 13 de 1993, Jaime Jaramillo 15016 (QCA-204514!).

Distribution and habitat. *Sloanea cayapensis* is a medium-sized tree only known from two localities on high alluvial terraces along the Cayapas River in the Lowland Evergreen Forests of Equatorial Chocó (Ministerio del Ambiente del Ecuador 2013). This area lies in the Chocó floristic province, where forest structure is characterised by a canopy 25–30 m high, with occasional emergent trees reaching 40 m. High levels of endemism and dominance of families, such as Moraceae, Fabaceae, Meliaceae, Myristicaceae and Lecythidaceae, have been reported for this area (Gentry 1982; Ministerio del Ambiente del Ecuador 2013) and the label of the type specimen indicates that *S. cayapensis* co-occurs with the following tree species: *Terminalia amazonia* (Combretaceae), *Swa rzia littlei* (Fabaceae), *Matisia cordata* (Malvaceae) and *Cordia alliodora* (Boraginaceae). The climate of this area is rainy near the Ecuador-Colombia border and becomes more seasonal to the south, where it transitions into the Lowland Seasonal Evergreen Forests of the Equatorial Chocó (Ministerio del Ambiente del Ecuador 2013).
Etymology. From the Spanish word Cayapa, with reference to the Chachi indigenous group that inhabits a great portion of the evergreen lowland forests of the Equatorial Chocó in Ecuador. The word Chachi means ‘pure’ in the Cha’palaachi language. The species name was first proposed by the late Ecuadorian botanist J. Jaramillo as a written annotation on herbarium specimens, but was never validly published.

Conservation status. *Sloanea cayapensis* may be catalogued as Endangered (EN) following IUCN (2012) criterion A2c, which indicates: “An observed, estimated, inferred or suspected population size reduction of ≥ 50% over the last 10 years or three generations, whichever is the longer, where the reduction or its causes may not have ceased or may not be understood or may not be reversible” and criterion B1ab(iii), which indicates: “Extent of occurrence (EOO) estimated to be less than 5,000 km² and estimates indicating continuing decline, observed, inferred or projected, in area, extent and/or quality of habitat”. The analysis using the GeoCat tool for geospatial conservation assessment determined an EOO of 2000 km² (Bachman et al. 2011). *Sloanea cayapensis* is only known from two localities on the banks of the Cayapas River, in the lowland evergreen forest of the Equatorial Chocó. The area has suffered extensive clear-cutting in the last 30 years, leading to a drastic reduction of native forests and expansion of oil palm plantations and illegal logging, these being the major threats faced by the species. Since collection of the types in 2003, no other specimens of this species have been recorded despite the fact that subsequent field trips have sampled the same habitat occupied by this species. Over the last 26 years, the annual rate of deforestation in the lowland evergreen forest of the Equatorial Chocó in Ecuador has been 1.7–2.9% and the remnant forests in this area cover just 24% of their original extent (Sierra 2013). Consequently, the habitat occupied by this species in Ecuador has been drastically reduced. However, the species is likely to occur in similar habitats in the Colombian Chocó where the dynamic of deforestation is less drastic but a cause for concern.

Discussion

Based on our description, *Sloanea cayapensis* is morphologically similar to *S. grandiflora* and *S. fragrans*, both members of the subgenus *Sloanea*. The new species can be readily distinguished from *S. fragrans* by having longer (3–3.5 mm vs. 1.5–2 mm long) and densely hirsute angle-striated filaments (vs. cylindrical puberulent filaments). It also differs from *S. fragrans* by having shorter anthers (1.5–2 mm vs. 2–3 mm long), acute or obtuse awn-shaped (vs. lanceolate) anthers densely hirsute (vs. glabrous to sub-glabrous), lanceolate stipules with entire margins (vs. navicular with remarkable irregular serrate margins) and shorter petioles (2–7.5 cm vs. 5.5–20(–25) cm long) (see Table 1).

*Sloanea cayapensis* is distinguished from *S. grandiflora* in having a densely hirsute style (vs. glabrous style at the apex and slightly pubescent at the base), thin connective (vs. very wide connective between the anthers sacs on the abaxial surface), thick and obtuse anthers (vs. linear-lanceolate) and an ovoid and densely hirsute ovary with 4 locules (vs. pubescent ovary with 4–6 locules). It also differs from *S. grandiflora* in
Table 1. Diagnostic characters for *Sloanea cayapensis* and its closest relatives, as well as their geographical distribution in the Neotropics: Western Amazon (WA), Central Amazon (CA), Chocó region (Chocó), Central America (CAm) and the Guiana Shield (GS).

<table>
<thead>
<tr>
<th>Characters</th>
<th>Sloanea cayapensis</th>
<th>Sloanea grandiflora</th>
<th>Sloanea fragrans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaf size</td>
<td>(18.8–342–52[–61.8] long, (9.5–17–26[–32] cm wide</td>
<td>21–43.5 cm long, 15–25.5 cm wide</td>
<td>45–65 cm long, 21–29.5 cm wide</td>
</tr>
<tr>
<td>Leaf shape</td>
<td>Obovate-spatulate</td>
<td>Elliptic to elliptic-ovate</td>
<td>Obovate</td>
</tr>
<tr>
<td>Leaf margins</td>
<td>Entire to shallowly sinuate</td>
<td>Irregularly dentate</td>
<td>Irregularly undulate</td>
</tr>
<tr>
<td>Stipules</td>
<td>Lanceolate with entire margins</td>
<td>navicular with irregular serrate margins</td>
<td>navicular with finely dentate margins</td>
</tr>
<tr>
<td>Stamens</td>
<td>5–6 mm long</td>
<td>7–9 mm long</td>
<td>4–8 mm long</td>
</tr>
<tr>
<td>Filaments</td>
<td>3–3.5 mm long densely hirsute angle-striated</td>
<td>2–4 mm long, angled or laterally flattened</td>
<td>1.5–2 mm long cylindrical puberulent</td>
</tr>
<tr>
<td>Anthers</td>
<td>1.5–2 mm long, thick and obtuse</td>
<td>3–4 mm long, linear-lanceolate</td>
<td>2–3 mm long, lanceolate</td>
</tr>
<tr>
<td>Ovary</td>
<td>Ovoid, 2–4 mm long, 1.5–2.7 mm wide</td>
<td>Ovoid, 4 mm long, 2.5 mm wide</td>
<td>Globose, 3 mm long, 3 mm wide</td>
</tr>
<tr>
<td>Style</td>
<td>Densely hirsute in its entire length up to 8 mm long</td>
<td>Pubescent at the base glabrous above, 7–9 mm long</td>
<td>Pubescent in its entire length, 5–10 mm long</td>
</tr>
<tr>
<td>Capsule</td>
<td>Globose densely covered by curled flexible spines</td>
<td>Ellipsoidal covered by stramineous flexible curled spines</td>
<td>Globose densely covered by short spines</td>
</tr>
<tr>
<td>Elevation</td>
<td>0–500 m</td>
<td>0–1500 m</td>
<td>0–1100 m</td>
</tr>
<tr>
<td>Geographic distribution</td>
<td>Chocó</td>
<td>WA, CA, GS and CAm</td>
<td>WA and CAm</td>
</tr>
</tbody>
</table>

having lanceolate stipules (vs. navicular stipules with finely dentate margins), shorter pedicels (4–11 mm vs. 7–25 mm) and strongly ascendant numerous secondary veins (11–20 vs. 13–15 slightly ascendant secondary veins).

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We thank the staff at the herbaria ECUAMZ, QCA, QAP and QCNE for their support and permission to access material deposited in these institutions. This work honours Jaime Jaramillo Asanza, a professor in the Biology Department at the Catholic University of Ecuador who made a great contribution to our knowledge of the Ecuadorian flora and who started a taxonomic revision of the genus *Sloanea* for Ecuador. Katya Romoleroux provided insightful comments to earlier versions of the manuscript.

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