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Bruguiera × *rhynchopetala* (Rhizophoraceae) newly reported in India, far west of south-east Asian, east Asian and western Pacific regions

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Abstract: *Bruguiera* × *rhynchopetala* (W.C.Ko) N.C.Duke & X.J.Ge, a natural hybrid between mangrove species, *B. gymnorhiza* (L.) Lam. and *B. sexangula* (Lour.) Poir., is newly reported for India. This is the first time a *Bruguiera* hybrid has been reported outside the south-eastern and eastern Asian and western Pacific region. The intermediate nature of this new entity for India was confirmed using morphometric analyses. It was observed within the reportedly threatened mangrove area of Vembanad lake which is the largest Ramsar site on the South West coast of India. These regions were noted for the co-occurrence of their putative parental taxa. Our report updates the currently existing distribution of *B.*×*rhynchopetala* and further challenges prior assumptions that populations of *B. gymnorhiza* and *B. sexangula* at their western limit of overlap show a greater degree of genetic separation between parent species. Also, it emphasises the urgency of conserving the Vembanad ecosystem and the biological diversity at risk.

Keywords: Hybrid, *Mangroves*, Morphometric analysis, Western Pacific region.

Introduction

Mangroves around the world are considered high priority ecosystems for global conservation because of their well-known environmental benefits (Polidoro *et al*., 2010). These specialised habitats of tree and shrub species constrained mostly within the upper tidal elevation range of warmer latitudes worldwide, contains 82 taxa in 32 genera from 17 plant families world wide (Tomlinson, 2016; Duke, 2017, 2020; Duke & Kudo, 2018; Saenger *et al*., 2019). A number of these taxa are natural hybrids, characterised by their intermediate, distinct and consistent morphological characteristics distributed over part of the parental species ranges that overlap (Ragavan *et al*., 2017).

The mangrove genus *Bruguiera* Lam., of family Rhizophoraceae Pers., has five species and three hybrids, and is distributed around the Indian subcontinent through Malesia to tropical Australia and islands in the western Pacific (Hou, 1958; Allen & Duke, 2006; Duke & Ge, 2011; Ragavan *et al*., 2016; Duke & Kudo, 2018). The key characteristics of the genus include: trees with short aerial roots, knee-like pneumatophores, stout buttresses, leaves with bijugate phyllotaxy, flower buds with more than six calyx lobes, bracteoles never enclosing the base of the flower, bilobed petals, slender stamens with contorted filaments and twice as many as petals, inferior ovaries, cup-shaped floral disc, and viviparous propagules with apically blunt hypocotyl (Sheue *et al*., 2005; Tomlinson, 2016).

The genus has been classified into two morphologically distinct groups of taxa: one group with smaller leaves and multi-flowered inflorescences of relatively small flowers, and the other group with larger leaves and single-flowered inflorescences. *Bruguiera parviflora* (Roxb.) Wight & Arn. ex Griff. and *B. cylindrica* (L.) Blume are (Lour.) Poir. are members of the latter group (Sheue *et al*., 2005; Duke & Ge, 2011; Tomlinson, 2016).

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Studies in the western Pacific region revealed the existence of hybrids between different species of *Bruguiera*. At present three recognised hybrids are in the genus, namely *B.* × *rhynchopetala* (W.C.Ko) N.C.Duke & X.J.Ge between *B. gymnorhiza* and *B. sexangula*, (Duke & Ge, 2011), *B.* × *hainesii* C.G.Rogers, between *B. cylindrica* and *B. gymnorhiza* (Cooper *et al*., 2016; Ono *et al*., 2016), and *B.* × *dungarra* N.C.Duke & Hidet. Kudo, between *B. exaristata* and *B. gymnorhiza* (Duke & Kudo, 2018). These hybrids were reported occurring in southern China, Malesia and northern Australia. Until now there have been no *Bruguiera* hybrids reported outside the south-eastern Asian, eastern Asian and western Pacific regions (Cooper *et al*., 2016; Ono *et al*., 2016).

Bruguiera × *rhynchopetala* was first reported from Hainan Island in China as a variety of *B. sexangula*, namely *B. sexangula* var. *rhynchopetala* W.C.Ko, 1978. It was observed only where *B. gymnorhiza* and *B. sexangula* grew in close proximity (Ko, 1978). Preliminary observations of morphological characters and subsequent genetic studies showed the entity to be an intermediate between *B. sexangula* and *B. gymnorhiza* (Ge, 2001; Ge *et al*., 2004, Pan *et al*., 2005; Islam *et al*., 2006; Zhou *et al*., 2008). Duke (2006) and Duke and Ge (2011) confirmed the hybrid status of *B.* × *rhynchopetala* based on morphometric assessment and ecological data. A global distribution map was developed for the three single-flowered *Bruguiera* species, *viz*., *B. exaristata*, *B. gymnorhiza* and *B. sexangula*. They also predicted that the hybrid might extend westward to southern India and Sri Lanka in the west. However, previous studies in Sri Lanka had been unable to locate *Bruguiera* hybrids in that region (Abeysinghe *et al*., 1999, 2000). This was taken as possible evidence that these hybrids may not occur in the western part of the overlap range of the putative parent species. Our new evidence redefines that understanding.

We present new findings that confirm the occurrence of *B.* × *rhynchopetala* on the south-western coast of the Indian subcontinent. In this way, we record the first occurrence of a *Bruguiera* hybrid outside of its previously known range in south-eastern Asian, eastern Asian and western Pacific regions. The new location is of further significance as this unusually biodiverse region suffers from notable degradation and loss of species (Asha *et al*., 2014).

Materials and Methods

Study site & field work: During the period between 2015–2019, field observations were first made at the Vembanad lake region and then extended to other regions of the Kerala coast of south-western India. Vembanad lake is the largest Ramsar site (9°30′ to 10°10′ N; 76°10′ to 76°25′ E; with an area of 233 km^2) in Kerala and the longest natural lake in India. As per the Environment Protection Act 1985 of the Government of India, Vembanad lake has been declared an 'Ecologically sensitive zone'. The study site was located along the south-western coast of the Indian peninsula (Padmalal *et al*., 1997; Shylesh & Ramaswamy, 2015) and spreads across three districts (Kottayam, Eranakulam and Alappuzha) of Kerala.

Morphological characters: Plant materials of all *Bruguiera* taxa present were collected from the overlapping zones of *B. sexangula* and *B. gymnorhiza* (Table 1). Morphological features of the samples were studied in detail. Measurements of both vegetative and reproductive parts were taken from fresh material. A set of 20 key numeric and multistate characters previously used by Duke and Ge (2011) were measured and recorded for each sample (Table 2). Four samples were taken from each tree, using averaged values for statistical analyses.

Numerical analysis: Two classificatory techniques, namely non-parametric ordination multidimensional scaling (MDS) and cluster analysis, were used for the analysis and comparison of the 20 characters listed in Table 2.. The tests followed standard methods and applied using PAST 4.03 software (https://past.en.lo4d.com/windows). Two dimensional MDS ordination was performed using the Gower similarity index. Cluster analysis was conducted using a Gower matrix of constrained data and paired group algorithm for the Unweighted Pair Group Method with Arithmetic mean (UPGMA) (Duke & Kudo, 2018)

Table 1. Collection details of samples used for morphological analyses of four *Bruguiera* species: *B. cylindrica*, *B. gymnorhiza*, *B. sexangula* and *B.* × *rhynchopetala*, from along the banks of Vembanad lake at four sites in three districts of Kerala state, India. Numbers for respective species indicate the number of samples considered, with the voucher number of these collections by P. Rajan given in brackets.

Site location, district	*B. cylindrica*	*B. gymnorhiza*	*B.* × *rhynchopetala*	*B. sexangula*
Thalayazham, Kottayam		8 (11010)	8 (11008)	8 (11009)
T.V.Puram, Kottayam		8 (11011)	8 (11013)	8 (11012)
Sreekantamangalam, Alappuzha		8 (11015)	8 (11014)	12 (11016)
Kochi, Ernakulam	32 (11020)	8 (11017)	8 (11019)	4 (11018)

Table 2. List of 14 numeric and 6 multistate* characters selected for statistical analysis.

Plant part	**No. of characters**	**Characters**
Leaves	5	Length (L, in cm) Width (W, in cm) Shape length (S, in cm), as length from widest width to petiole juncture Length/width (L/W) ratio Length/shape (L/S) ratio
Inflorescence	1	Number of flower buds
Mature flower buds	11	*Bud tip shape pointed or blunt Bud tip length (mm) Calyx lobe number Calyx lobe length (mm) *Petal hairs on outer margin hairy, sparsely hairy or glabrous Petal bristle number Petal bristle length (mm) Petal spine length/petal lobe length ratio *Petal tip shape obtuse or acute *Calyx lobe margin flat or raised *Calyx tube smooth or ribbed
Mature hypocotyls	3	*Calyx lobe shape reflexed or adpressed Length (L, in cm) Length/shape (L/S) ratio, where shape (S) is length from widest width to distal end

Results

Within the entire Kerala coastal region, the distribution of the presumed *B.* × *rhynchopetala* was restricted to the overlapping zones of *B. gymnorhiza* and *B. sexangula*. These zones were located along the banks of Vembanad lake.

Morphological characters of the genus

A comparison of key numeric and multistate characters of four *Bruguiera* taxa (*B. cylindrica*, *B. gymnorhiza*, *B. sexangula* and *B.* × *rhynchopetala*) was made (Table 3).

Among the four taxa, *B. cylindrica* was distinguished by the presence of multiple flowers in inflorescences, comparatively smaller leaves, flowers, petals and anthers. Other distinguishing features of the taxon included: blunt flower bud tips, greenish white coloration, smooth, glabrous calyx tubes, white petals, hairs all over the petal, and calyx lobes completely

Table 3. Morphological numerical ranges* and multistate characteristics of key characters for three *Bruguiera* species and *B.* × *rhynchopetala* occurring in Kerala state, India. (* For abbreviations, L = length, W = width, S = length from the widest width to distal end, L/W is the ratio of length/width, L/S is the ratio of length/shape (S); for units, cm used for leaves and mature hypocotyls, and mm used for mature flower buds.

Plant part	**Character**	*B. cylindrica*	*B. gymnorhiza*	*B.* × *rhynchopetala*	*B. sexangula*
Leaves	L	7.2–12.5	14–22.7	11.3–20	12–18.1
	W	2.5–4.7	4–6.6	3.9–6.8	4.2–5.7
	S	4.3–8.5	8.7–14.2	7.3–13.7	7.4–12.3
	L/W	2.5–2.9	3.2–3.7	2.6–3.4	2.9–3.2
	L/S	1.5–1.7	1.5–1.62	1.51–1.68	1.5–1.6
Inflorescence	Number of flower buds	3	1	1	1
Mature flower buds	Bud tip shape	Blunt	Pointed	Pointed	Pointed
	Bud tip length	1–1.1	4.7–5.1	3.5–4.23	4–4.6
	Calyx lobe number	8–9	12–13	11–12	10–11
	Calyx lobe length	0.5–0.8	2–2.2	1.7–2.1	1.7–2
	Petal hairs on outer margin	Hairy	Glabrous, or sparsely hairy	Glabrous, or sparsely hairy	Hairy
	Petal bristle number	3	2–3	1–2	0–1
	Petal bristle length	0.1–0.15	0.2–0.25	0.05–0.15	0.07–0.1
	Petal spine length/lobe length ratio	1.1–1.2	1	0.83–0.92	0.83
	Petal tip shape	Obtuse	Acute	Obtuse to acute	Obtuse
	Calyx lobe margin	Flat	Flat	Raised to flat	Raised
	Calyx tube	Smooth	Smooth	Ribbed	Ribbed
Mature hypocotyls	Calyx lobe shape	Reflexed	Adpressed	Slightly reflexed	Slightly reflexed
	Length	7.9–10	11–19	9–11.6	7.2–9.1
	Length/shape (LS) ratio	1.2–1.63	1.4–1.8	1.39–1.48	1.42–1.6

reflexed in mature hypocotyls. This species was considered to be the outlier taxon in our analyses.

The other three single-flowered taxa showed characters similar to each other. These similarities included the comparatively larger flower bud, greenish to reddish calyces, smooth or ribbed calyx tubes, orange bilobed petals with a petal spine between lobes and wider hypocotyls. Characters that were used to discriminate these taxa include: hairs along petal margins, the number of petal bristles and ribbing of the calyx tube.

Numerical analysis

Numerical analyses of 20 morphological (vegetative and floral) characters of *Bruguiera* taxa sampled in the Kerala state of India, confirmed the presence of *B.* × *rhynchopetala* and its intermediate position between *B. gymnorhiza* and *B. sexangula*. The UPGMA cladogram (Fig. 1) derived from a cluster analysis and the non-parametric ordination of multidimensional scaling (MDS) showed there was no overlap between individual groupings of the local species entities of *B. gymnorhiza*, *B. sexangula*, *B.* × *rhynchopetala* and *B. cylindrica* (Fig. 1). The MDS plot had the three species placed roughly at three corners of a triangle, while the hybrid entity was positioned between *B. gymnorhiza* and *B. sexangula* (Fig. 1).

Taxonomic Treatment

We provide a botanical description of the new Indian entity because it has subtle differences from its congeners in SE Asia and the western Pacific.

Bruguiera × rhynchopetala (W.C.Ko) N.C.Duke & X.J.Ge, Blumea 56: 45. 2011. *Bruguiera sexangula* (Lour.) Poir. var. *rhynchopetala* W.C.Ko, *Acta Phyotax. Sin.* 16: 110. 1978. *Type*: CHINA, **Hainan**, Qiongshan, Yanfeng, mangrove, 09.09.1974, Yue-74, 03190 (IBSC).

Bruguiera × *rhynchopetala* N.C.Duke, Australia's Mangroves 122–123. 2006., *nom. nud.* **Fig. 2**

Evergreen trees with columnar branched stem, flat fin-like buttresses at base. Pneumatophores knee-like, exposed, often with flaking bark. Stem with large corky lenticels, each 1–2 cm diam., more on buttresses. Stipules interpetiolar, paired, enclosing terminal bud, to 7 cm long, lanceolate, green with pinkish tinge. Leaf scars prominent on twig stems of leafy shoot, below apical shoot. Leafy shoot with 8–12 leaves in clusters. Leaf simple, opposite, bijugate; petioles 2.8–4.5 cm long; laminae elliptic, 11–21 × 4–7 cm, 2.8–3.5 times longer than wide, petiolate, base cuneate, margins entire, apex acute, blade glossy green.

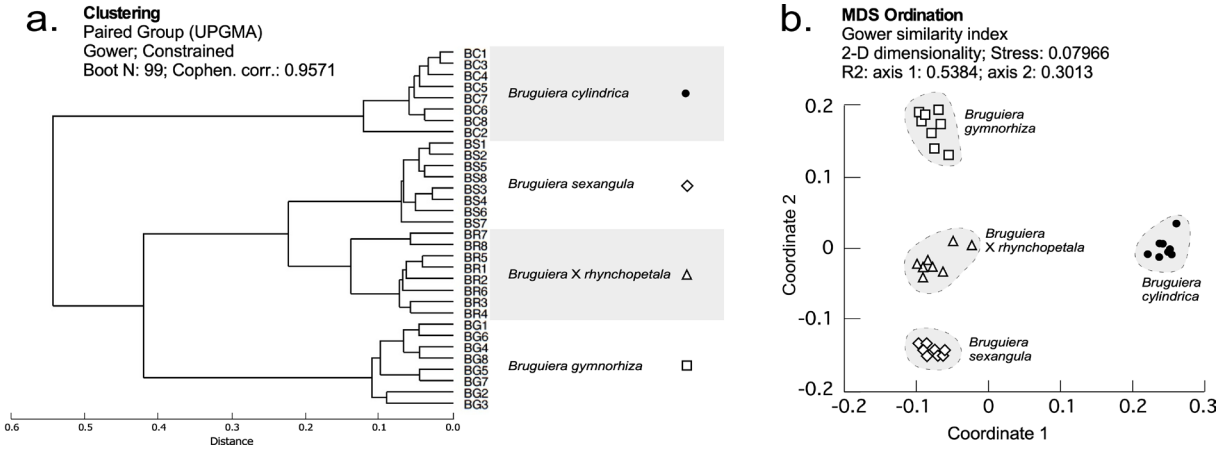

Fig. 1. A clustering dendrogram (a) and an ordination analysis plot (b) showing relationships between *Bruguiera* × *rhynchopetala* (W.C.Ko) N.C.Duke & X.J.Ge, and its putative parent taxa, *B. sexangula* (Lour.) Poir. and *B. gymnorhiza* (L.) Lam., plus the outlier congeneric species, *B. cylindrica* (L.) Blume.

Inflorescence axillary, 1-flowered; buds generally nodding, maturing within leafy rosette; peduncles green, 6–12 × 2–3 mm. Mature flower bud placed at 1–2 internodal segments below apical shoot, 35–40 mm long, distal tip acute, green to yellow. Calyx mostly ribbed; lobes 11–12, longer than tube, slender and pointed, margins slightly raised. Petals bilaterally folded, bilobed, creamy white in immature bud, becoming orange when mature; outer margins glabrous or with sparsely distributed hairs, tuft of hairs at base; lobe tip rounded with two unequal bristles (larger one 1–1.2 mm long) near apex, rarely one. Anthers linear, in pairs, creamy pale yellow turning brown at anthesis. Style filiform, centrally placed, 3–4 lobed at tip, smooth, pale green. Fruit cryptic in calyx tube. Mature hypocotyls at 4–6 internodal segments below apical shoot, cigar-shaped, stout, slightly ribbed longitudinally, distal end blunt, green; plumule 2–3 mm long; calyx lobes slightly reflexed.

Flowering & fruiting: Flowering is observed throughout the year. Peak flowering period is recorded between September and December. Mature propagules are observed throughout the year but peak during December to March.

Habitat: *Bruguiera* × *rhynchopetala* occurs in low salinity backwater zones like Vembanad lake where it co-exists with *B. gymnorhiza* and *B. sexangula*.

Distribution: This taxon occurs from Hainan Island (southern China) to the Solomon Islands and north-eastern Australia at its eastern limit, extending west to India. In India, the taxon is known only from Kerala. Knowledge of any wider distribution of this taxon at this revised range limit in the Indian region appears incomplete.

Specimens examined: **Bruguiera × rhynchopetala:** INDIA, **Kerala**, Alappuzha district, Sreekanta mangalam vicinity, near high intertidal edge of Vembanad lake, N 9.66°, E 76.36°, 21.03.2019, *Prasanna Rajan* 11014 (CATH); Ernakulam district, mangroves near high intertidal edge of Vembanad lake, N 10.00°, E 76.22°, 27.03.2019, *Prasanna Rajan* 11019 (CATH); Kottayam district, Thalayazham vicinity, mangroves near high intertidal edge of Vembanad lake, N 9.69°, E 76.41°, 18.03.219, *Prasanna Rajan* 11008 (CATH); T.V. Puram vicinity, mangroves near high intertidal edge of Vembanad lake, N 9.70°, E 76.39°, 18.03.2019, *Prasanna Rajan* 11013 (CATH).

Bruguiera cylindrica: INDIA, **Kerala**, Ernakulam district, mangroves near high intertidal edge of Vembanad lake, N 10.00°, E 76.22°, 27.03.2019, *Prasanna Rajan* 11020 (CATH).

Bruguiera gymnorhiza: INDIA, **Kerala**, Alappuzha district, Sreekantamangalam vicinity, near high intertidal edge of Vembanad lake, N 9.66°, E 76.36°, 21.03.2019, *Prasanna Rajan* 11015 (CATH); Ernakulam district, mangroves near high intertidal edge of Vembanad lake, N 10.00°, E 76.22°, 27.03.2019, *Prasanna Rajan* 11017 (CATH); Kottayam district, Thalayazham vicinity, mangroves nearhigh intertidal edge of Vembanad lake, N 9.69°, E 76.41°, 18.03.2019, *Prasanna Rajan* 11010 (CATH); T.V. Puram vicinity, mangroves near high intertidal edge of Vembanad lake, N 9.70°, E 76.39°, 18.03.2019, *Praanna Rajan* 11011 (CATH).

Bruguiera sexangula: INDIA, **Kerala**, Alappuzha district, Sreekantamangalam vicinity, near high intertidal edge of Vembanad lake, N 9.66°, E 76.36°, 21.03.2019, *Prasanna Rajan* 11016 (CATH); Ernakulam district, mangroves near high intertidal edge of Vembanad lake, N 10.00°, E 76.22°, 27.03.2019, *Prasanna Rajan* 11018 (CATH); Kottayam district, Thalayazham vicinity, mangroves near high intertidal edge of Vembanad lake, N 9.69°, E 76.41°, 18.03.2019, *Prasanna Rajan* 11009 (CATH); T.V. Puram vicinity, mangroves near high intertidal edge of Vembanad lake, N 9.70°, E 76.39°, 18.03.2019, *Prasanna Rajan* 11012 (CATH).

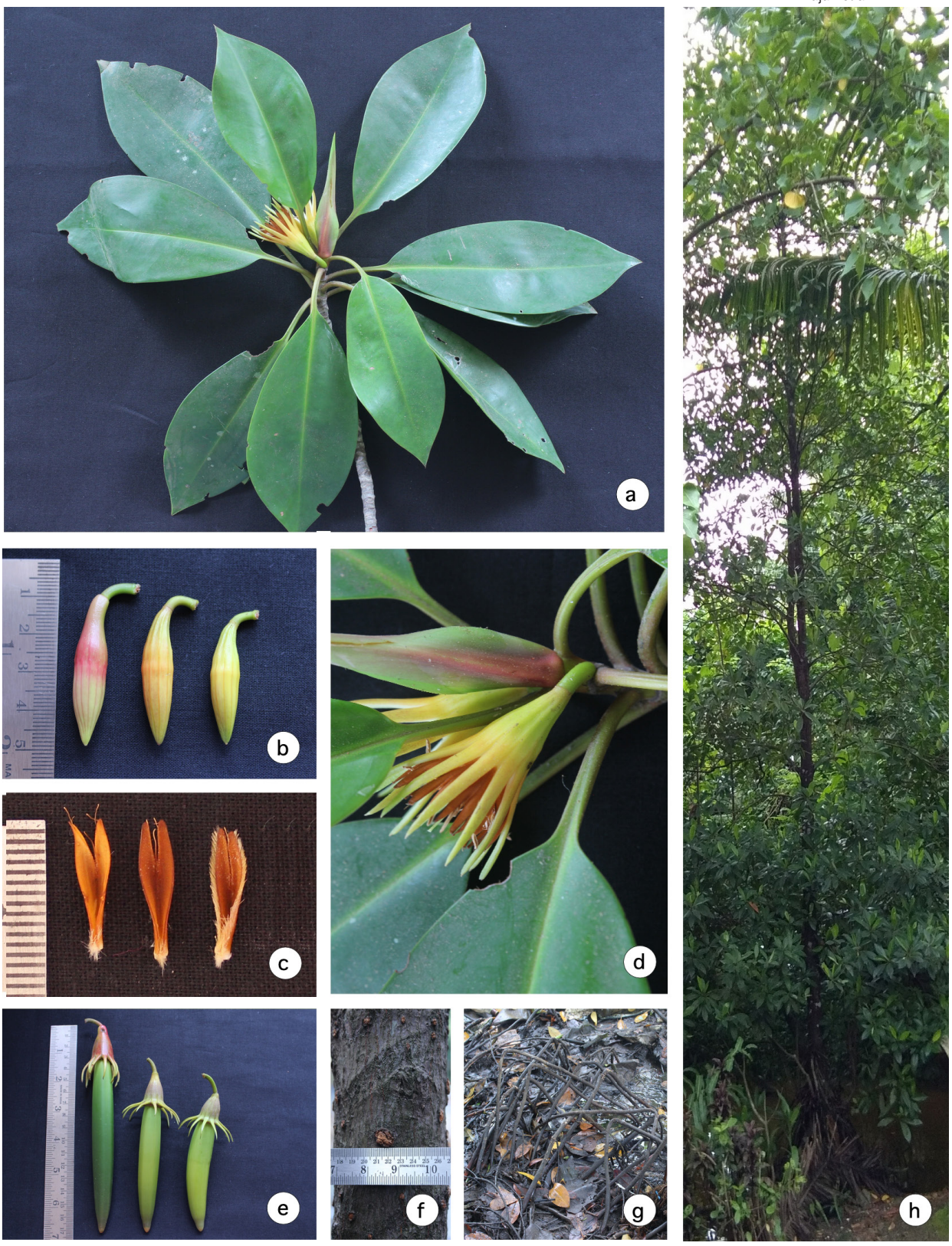

Fig. 2. *Bruguiera* Lam. taxa occurring in Kerala, India: **a.** Leafy shoot of *Bruguiera* × *rhynchopetala* (W.C.Ko) N.C.Duke & X.J.Ge; **b.** Mature flower buds of three species (left to right): *B. gymnorhiza* (L.) Lam., *B.* × *rhynchopetala*, *B. sexangula* (Lour.) Poir.; **c.** Dehisced petals of three species (left to right): *B. gymnorhiza*, *B.* × rhynchopetala, *B. sexangula*; **d.** Single flower of B. × rhynchopetala; **e.** Mature hypocotyls of three species (left to right): *B. gymnorhiza*, *B.* × *rhynchopetala*, *B. sexangula*; **f.** Bark and lenticels of *B.* × *rhynchopetala*; **g.** Knee roots of *B.* × *rhynchopetala*; **h.** Habit of *B.* × *rhynchopetala* (photos by Sijo Mathew).

Key to *Bruguiera* taxa in mainland India

1. Flowers in inflorescence, always less than 2 cm in length; hypocotyl widest diameter less than 1 cm 2
1. Flowers solitary, always greater than 3 cm in length; hypocotyl widest diameter greater than 1 cm 3
2. Calyces with reflexed lobes reflexed in fruit .... *B. cylindrica*
2. Calyces with completely adpressed lobes in mature hypocotyls ..... *B. parviflora*
3. Petals with margins fringed with hairs, lobe apices glabrous or if bristles present, equal to or less than 1 mm in length ..... *B. sexangula*
3. Petals with margins without fringed hairs, lobe apices with 1–3 bristles, greater than 1 mm in length 4
4. Petals with 2–3 bristles, greater than 2 mm in length ..... *B. gymnorhiza*
4. Petals with 1–2 bristles, less than 2 mm in length ..... *B.* × *rhynchopetala*

Discussion

Of primary note, *B.* × *rhynchopetala* reported in the present study was not fully consistent with descriptions of this taxon from the western Pacific (Sheue *et al*., 2005, Duke & Ge, 2011;). Differences were observed in various characters notably with regard to the petal margins being mostly glabrous in Indian material instead of having fringing hairs along the margins. In addition, petals in Indian specimens had two unequal bristles instead of 2–3 bristles, while the calyces were ribbed instead of being variable. While these differences were notable, they were not considered sufficient for further specific differentiation based on current collections at this newly established western limit. It was further relevant that the intermediate taxon, *B.* × *rhynchopetala* was located in close proximity to both *B. gymnorhiza* and *B. sexangula*. Additional studies could contribute to further elucidating the morphological differences amongst Indian collections of *B. gymnorhiza a*nd *B. sexangula*, as well as presenting an evaluation of possible genetic traits, comparing populations across their global range.

In eastern populations of *B. sexangula*, there were comparatively short bristles reported on petal lobes (Duke & Ge, 2011) matching those in Indian populations. In addition, *B. sexangula* had hairs fringing petal margins, petal bristles were absent or singular if present, with lengths less than 1 mm or minute, petal lobe tips obtuse, and calyx lobes slightly reflexed on mature hypocotyls.

In Indian sites, *B. gymnorhiza* had acute petal lobe tips, petals with two or three bristles greater than 2 mm long, with margins mostly glabrous or sparsely hairy. To the east, the petal margin character was reported as variable often with fringing hairs (Sheue *et al*., 2005; Duke & Ge, 2011; Ragavan *et al*., 2016). These observations identified an apparent difference in diagnostic characters between regions. But, as shown in the MDS plot (Fig. 1b), there appeared to be only minor variation in overall characters where *B.* × *rhynchopetala* specimens were positioned more or less equidistant between *B. sexangula* and *B. gymnorhiza* (similar to that shown by Duke & Ge, 2011). Based on current evidence, we conclude that the intermediate taxon is most likely to be the hybrid *B.* × *rhynchopetala*, positioned between its putative parent species, *B. sexangula* and *B. gymnorhiza*. Although, as noted, the later taxon had distinct morphological differences from populations in the east.

We are aware of other potentially diagnostic characters, like the colleters at the base of the conspicuous interpetiolar stipules of this genus (Hou, 1958; Sheue *et al*., 2013). However, for this assessment, we have relied on morphological characters known to be diagnostic for comparable taxa within this genus worldwide (Duke & Ge, 2011; Cooper *et al*., 2016; Duke & Kudo, 2018).

In summary, *B.* × *rhynchopetala* differs from *B. sexangula* but is similar to *B. gymnorhiza* in not having fringed hairs at the petal lobe margin, similar length of the petal lobe and petal lobe tip shape. While the hybrid is similar to *B. sexangula* but differs from *B. gymnorhiza* in

having ribbed calyx tubes, fewer calyx lobes that are slightly reflexed in mature hypocotyls.

Reports until now revealed the existence of a hybrid intermediate only in countries in the eastern portion of the parental overlap zone in both northern and southern hemispheres like southern China, Malesia, Papua New Guinea and northern Australia (Duke & Ge, 2011; Muhamad *et al*., 2016; Tomlinson, 2016; Duke, 2017). This observation led to a working view that *B. gymnorhiza* and *B. sexangula* populations in the west (southern India and Sri Lanka) may have greater genetic separation, as an explanation for the apparent lack of hybrids in the western part of the range (Sheue *et al*., 2005; Duke & Ge, 2011). With this new observation of a distant population of *B.* × *rhynchopetala* beyond its known south-eastern Asian, eastern Asian and western Pacific distribution (Fig. 3), we raise important questions about the description and identification of *Bruguiera* taxa throughout the region. Such questions warrant further investigations across the region to develop a clearer understanding of morphological and genetic differences between eastern and western populations.

The distribution of *B. sexangula* appears limited further to comparatively lower salinity backwater zones, while *B. gymnorhiza* occurs naturally in a their possible niche separation (Duke, 2006). The hybrid was observed mostly in back water zones where *B. sexangula* was more abundant than *B. gymnorhiza* (also consider Zhou *et al*., 2008).

In addition, as well as being of great biogeographical and socio-economic significance, the Vembanad wetland ecosystem is facing notable threats from environmental degradation (Asha *et al*., 2014). The mangrove forests of Kerala are now only a remnant of their past extent (Mini *et al*., 2014). During the last three decades, the Kerala coast has lost a significant proportion of its mangrove forests (Sreelekshmi *et al*., 2020), the destruction is much higher in the Ernakulam district with remaining mangrove and natural estuarine areas located mostly around the Vembanad lake (Rani *et al*., 2018; Sreelekshmi *et al*., 2020). During the period between 1973 and

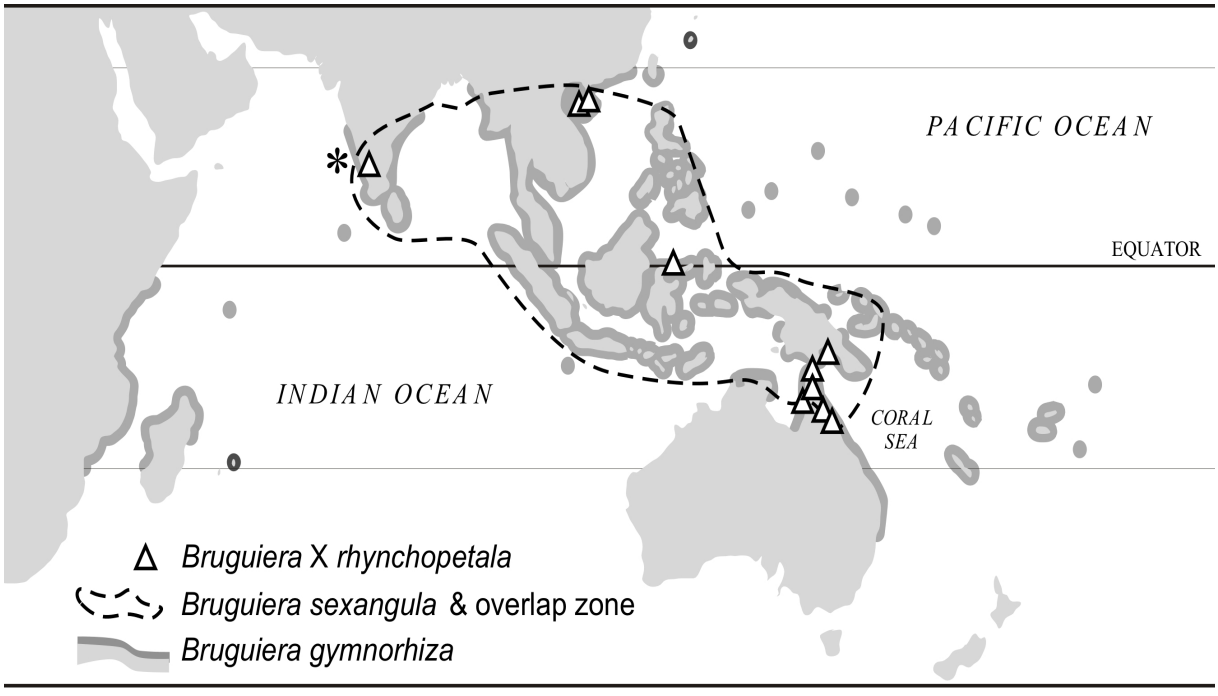

Fig. 3. Distribution of *Bruguiera* × *rhynchopetala* (W.C.Ko) N.C.Duke & X.J.Ge collections compared to the overlapping distributional ranges of parent taxa *B. gymnorhizha* (L.) Lam. and *B. sexangula* (Lour.) Poir. (Duke & Ge, 2011; Duke, 2017); (Asterisk *marks the newly reported location recorded in this publication).

2015, there were losses of 6.93% (~12.28 km²) (Parvathy & Babu, 2016). Accordingly, our current observations not only update the distribution status of *B.* × *rhynchopetala*, but they also emphasise the great need for urgent conservation of these valued but threatened ecosystems of south-western India.

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