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Research

Critical notes on the identity and distribution of *Sonneratia griffithii* Kurz (Lythraceae) in India – a critically endangered mangrove species

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The identity and distribution in India of *Sonneratia griffithii* Kurz, a critically endangered mangrove species, is validated and corrected. Field surveys showed that *S. griffithii* only occurs in the Andaman Islands and that specimens from the Indian Sundarbans and Odisha previously misidentified as *S. griffithii* instead belong to *S. alba*. An updated taxonomic description and illustration is provided, and the key distinguishing characters of the *Sonneratia* species found in the study are discussed with the aim to solve any uncertainty about the identity and nomenclature of Indian *Sonneratia* species.

Keywords: Andaman Islands, mangroves, Sundarbans, taxonomy

Introduction

Sonneratia L. f. (Lythraceae sensu lato), is a genus of true mangroves widely distributed from eastern Africa through Indo-Malaya to northeastern Australia and some islands in the West Pacific Ocean (Duke 2006, Tomlinson 2016). It consists of six species (*S. alba* Smith., *S. apetala* Buch.-Ham., *S. caseolaris* (L.) Engl., *S. griffithii* Kurz, *S. lanceolata* Blume and *S. ovata* Backer), and three inter-specific hybrids (*S. × gulngai* N.C. Duke, *S. × urama* N.C. Duke and *S. × hainanensis* W.C. Ko, E.Y. Chen & W.Y. Chen) (Tomlinson 2016). All the six species and two inter-specific hybrids (all but *S. × hainanensis*) have been reported to occur in Indian mangroves (Ragavan et al. 2016). Among the six species, *S. alba* has the widest distribution, followed by *S. caseolaris*, *S. ovata* and *S. apetala*. *Sonneratia lanceolata* and *S. griffithii* are narrowly distributed species, and *S. griffithii* is categorised as “critically endangered” (Polidoro et al. 2010) and known to occur only along the shores of the Andaman Sea, northward to Bengal and southward to the upper Malay Peninsula and Sumatra



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(Tomlinson 2016). Although reported to be locally common, it has rarely been collected and good herbarium specimens are not available. Thus, the taxonomic identity and distribution of *S. griffithii* remains elusive globally as well as in India and the species name is categorised as “unresolved” in The Plant List (2013).

Sonneratia griffithii was first described by Kurz (1871) as a new species from Burma, but he recorded only those characters that distinguish this species from *S. caseolaris* and *S. alba*. The shape of the flower bud and bud apex were considered the key distinguishing characters between *S. alba* (oblong elliptic and acute) and *S. griffithii* (rounded and obtuse), whereas the presence and absence of petals was considered the key distinguishing character between *S. caseolaris* and *S. griffithii*, respectively. Also in a subsequent publication, Kurz (1875) retained his earlier taxonomic diagnosis. However, the species was described in greater detail by him in his Forest Flora of Burma (Kurz 1877). Later, Clarke (1879) and King (1898) considered *S. griffithii* as an apetalous form of *S. acida* Smith (= *S. caseolaris*), and King (1898) reduced it to a variety as *S. acida* var. *griffithii* King. Thereafter, Brandis (1906) and Troup (1921) included *S. griffithii* in the Flora of British India (includes both present Indian Territory and Burma (= Myanmar)) based on the reports of Kurz (1871), Clarke (1879) and King (1898). However, they noted that *S. griffithii* occurred only in Burma. Prain's comprehensive account on Bengal Plants also did not report *S. griffithii* from India (Prain 1903). Parker (1925) and Backer and Van Steenis (1951) in their revision of the Sonneratiaceae in Tenasserim and the Indo-Malay region, respectively, also did not report *S. griffithii* from the Indian mainland, but they reported its occurrence in the Andaman Islands.

Despite Smith's (1819) diagnosis of *S. alba*, *S. caseolaris* (*S. acida*) and *S. apetalata*, the presence of petals in *S. alba* was somehow overlooked by him, as well as by Rumphius (1741) and Linnaeus (1754). Thus, most subsequent authors (Kurz 1871, 1875, 1877, Clarke 1879, King 1898, Brandis 1906, Troup 1921) treated *S. alba* as apetalous along with *S. griffithii* and *S. apetalata*. Apparently, the obscure and short-lived nature of the petals and the lack of insufficient material for critical examination led researchers to treat *S. alba* as an apetalous form. However, Parker (1925) and Backer and Van Steenis (1951) reported the presence of petals in *S. alba*, made a clear distinction between *S. alba* and *S. griffithii*, and reconsidered their distribution. Nevertheless, most Indian authors continued to accept *S. griffithii* from the Indian mainland (Naskar 1983, 2004, Banerjee 1986, Naskar and Guha Bakshi 1987, Banerjee and Rao 1990, Naskar and Mandal 1999, Mandal and Naskar 2008, Kathiresan 2010). Furthermore, the taxonomic descriptions and distributional data provided by these authors were incongruent and often confusing. The descriptions, distributional notes and images/specimens given by these authors show that they have misidentified *S. alba* as *S. griffithii*.

Sonneratia griffithii was first reported from Indian Sundarbans by Naskar (1983). The images of *S. griffithii* in his subsequent publications (Naskar and Mandal 1999,

Naskar 2004) shows obovate leaves with cuneate base, elliptic buds with acute tip, ribbed and cup shaped calyx, linear white petal, red inner side of calyx lobes and sickle-shaped seeds. All these characters are diagnostic features of *S. alba* (Backer and Van Steenis 1951, Duke and Jackes 1987), whereas *S. griffithii* is characterised by having obovate or suborbicular leaves with rounded base, rounded buds with obtuse tip, smooth calyx, greenish or yellowish white inner side of calyx lobes and irregular seeds (Backer and Van Steenis 1951). Banerjee (1986) reported *S. griffithii* from the Maipura River mouth in Cuttack district of Odisha. However, his taxonomic notes and herbarium specimens deposited at CAL (collection no. 18227, 10230, 9471, 10263, 10260, 9471, 10230) show that he misidentified *S. alba* as *S. griffithii*. Furthermore, in his subsequent reports (Banerjee et al. 1989, Banerjee and Rao 1990), he noted that *S. griffithii* is found only in Odisha in mainland India, whereas *S. alba* is restricted to the Andaman Islands and a few places along the west coast. Naskar and Mandal (1999) also made the same observation on the distribution of *S. alba* and *S. griffithii* in India. Parkinson (1923) reported two species of *Sonneratia* from Andaman Islands viz., *S. alba* Smith and *S. acida* Smith, but from his description for *S. acida* (pointed bud and linear white petal) and *S. alba* (rounded bud and absence of petal), it is evident that *S. alba* was considered as *S. acida* and *S. griffithii* as *S. alba*. Subsequently, Parker (1925) also reported the occurrence of *S. griffithii* in Andaman Islands based on specimens collected from Andaman Islands by Parkinson (CAL-accession no. 1115, 1148!), but subsequent researchers treated Parkinson's *S. acida* as *S. caseolaris* and *S. alba* (i.e. *S. griffithii*) as *S. alba*. Furthermore, Dagar et al. (1991) and Debnath (2004) doubted the occurrence of *S. griffithii* in Andaman Islands. Recently Ragavan et al. (2013) reported the occurrence of *S. griffithii* from Andaman Islands without any critical notes and herbarium information

It is thus evident from earlier descriptions and notes that *S. alba* has commonly been misidentified as *S. griffithii* and therefore, distributional records of *S. griffithii* in India are inaccurate. Therefore, a critical evaluation of collected plant material and available reports on *S. griffithii* from India are urgently needed. As *S. griffithii* is considered a globally threatened mangrove species with a declining population trend, information on its correct identity and extent of occurrence is very important. Hence, the present study was undertaken to provide correct identity and distribution of *S. griffithii* in India based on field surveys, analysis of relevant literature (including protologues) and examination of specimens preserved in CAL and PBL.

Material and methods

A qualitative field survey conducted in the Indian Sundarbans, Odisha coast and Andaman Islands over 79 selected sites (Fig. 1, Supplementary material Appendix 1) during 2016 to 2018 revealed the presence *Sonneratia griffithii* only in Andaman Islands. All the sites were visited

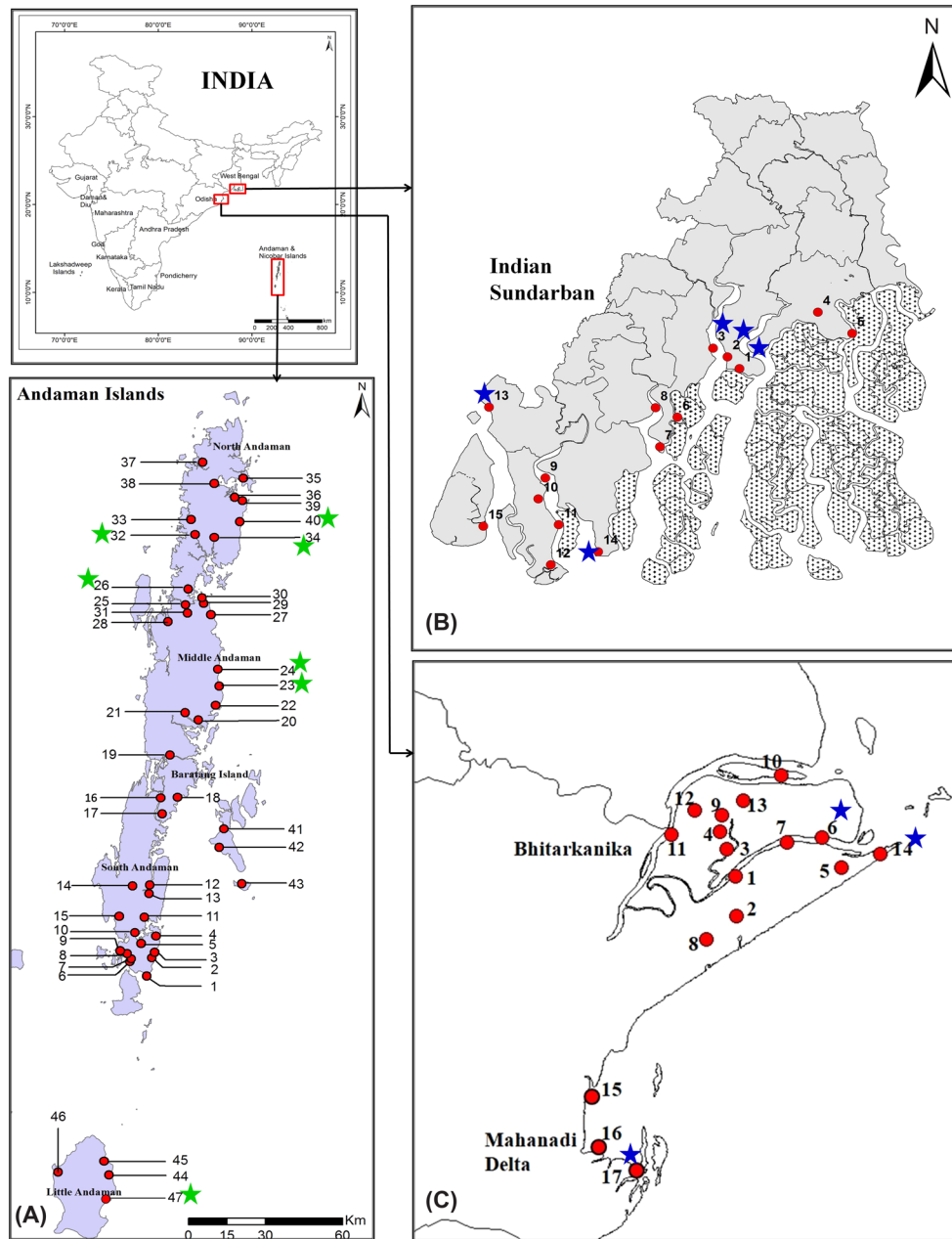


Figure 1. Map showing the study area. Red spots indicate sites surveyed in Andaman and Nicobar Islands, Indian Sundarban and Odisha coast. Green star indicates localities of *Sonneratia griffithii* in Andaman Islands, and blue star indicates a locality of *S. alba* in Sundarban and Odisha Coast. (A) Andaman Islands: 1 Chidiyatapu; 2 Burmanallah; 3 Beadonabad; 4 Corbyn's Cove; 5 Sippighat; 6 Manjeri; 7 Guptapara; 8 Manglutan; 9 Wandoor; 10 Ograbraj; 11 Bambooflat Creek; 12 Shoal Bay Creek; 13 Wright Myo creek; 14 Jirkatang; 15 Tirur; 16 Middle Strait; 17 Wrafter's Creek; 18 Baludera; 19 Kadamtala Creek; 20 Yerrata Creek; 21 Shyamkund Creek; 22 Rangat Bay; 23 Panchawati; 24 Betapur Creek; 25 Austin Creek; 26 Mohanpur Creek; 27 Karmatang Creek; 28 Chainpur Creek; 29 Rampur; 30 Danapur; 31 Tugapur; 32 Parangara Creek; 33 Kishorinagar Creek; 34 Kalighat Creek; 35 Smith Island; 36 Ariel bay; 37 Radhanagar; 38 Lakshnipur; 39 Durgapur; 40 Ramnagar; 41 Govindnagar; 42 Radhanagar; 43 Neil Island; 44 V.K. Pur Creek; 45 Dugong Creek; 46 Jackson Creek; 47 Hutbay. (B) Indian Sundarban: 1 Jharkhali; 2 Jharkhali Rajamore; 3 Gopalganj; 4 Jyotirampur; 5 Satjelia; 6 Debipur-Gurguria; 7 Kishorimohanpur-Baikunthpur; 8 Burje island-Bhubhaneswari; 9 Krishnapur-Prentice island; 10 Isawripur; 11 Chandanpiri; 12 Henery Island; 13 Lakshnipur; 14 Gobardhanpur-Buraburir; 15 Chemaguri. (C) Odisha Coast: 1 Gupti; 2 Satabhaya; 3 Bagagahan; 4 Bhitarkanika; 5 Habelikhati; 6 Maipura river basin 1; 7 Maipura river basin 2; 8 Krishnapriyapur; 9 Dangmal; 10 Kalibhanjadiya Island; 11 Khola; 12 Ragarapatia; 13 Mahishamunda; 14 Ekakula; 15 Mahanadi Delta 1; 16 Mahanadi Delta 2; 17 Mahanadi Delta 3.

at least once at the time of flowering to enable identification based on diagnostic floral characters. Specimens were collected to assess the numeric and multistate attributes of a wide range of vegetative and reproductive morphological characters and specimens were identified using regional floras (Kurz 1971, 1975, 1977, Mooney 1950, Clarke 1879, Prain 1903, Parkinson 1923, Parker 1925), monographs (Backer and Van Steenis 1951, Duke and Jackes 1987), and standard references (Giesen et al. 2006, Tomlison 2016). Collected specimens were also compared with specimens deposited at the Andaman and Nicobar Regional Centre, Botanical Survey of India (BSI), Port Blair (PBL), and Central National Herbarium, BSI, Kolkata (CAL). Electronic resources such as the Angiosperm Phylogeny Website (Stevens 2001), Tropicos of Missouri Botanical Garden (2015), World Biodiversity Information Network (REMIB), Kew Herbarium Database, Global Plants Initiative, electronic Plant Information Centre (ePIC 2002) and The International Plant Names Index (IPNI 2012) were also consulted. Voucher specimens of *S. griffithii* have been deposited at CSIR-National Botanical Research Institute, Lucknow (LWG, accession no. 103096, 103097) and PBL (accession no. 30963, 30964). In addition, specimens of *S. alba* collected from Indian Sundarbans (accession no. 103081-103086) and Odisha Coast (accession no. 103087-103092) have also been deposited at LWG.

Results

The present study revealed the presence of *Sonneratia griffithii* at seven localities (Panchawati, Betapur creek, Parangara creek, Mohanpur, Kalighat Creek, Ramnagar and Hut bay) in the Andaman Islands (Fig. 1A). In addition *S. alba*, *S. caseolaris* and *S. ovata* were also found in Andaman Islands. In Indian Sundarbans and Odisha coast, our study revealed the occurrence of three species of *Sonneratia*, viz., *S. alba*, *S. apetala* and *S. caseolaris*, of which, *S. apetala* and *S. caseolaris* were found to be common, whereas *S. alba* is rare in both regions. We found a few individuals of *S. alba* at five localities (Jharkhali, Jharkhali Rajamore, Gopalganj, Lakshmipur and Gobardhanpur) of Indian Sundarbans (Fig. 1B) and at three localities (Maipura river basin 1, Ekakula and Mahanadi Delta 1) in Odisha coast (Fig. 1C). In contrast to Indian Sundarbans and Odisha, *S. alba* is widely distributed in Andaman Islands.

The key distinguishing characters of *Sonneratia* species in India is given in Table 1. Based on the analysis of specimen deposited at CAL we found that many specimens of *S. alba* collected from Mahanadi Delta by L. K Banerjee (collection no. 18227, 10230, 9471, 10263, 10260, 9471, 10230), were misidentified as *S. griffithii* and there were no specimens of *S. griffithii* from Indian Sundarbans. Specimens deposited

Table 1. Diagnostic characters of *Sonneratia* recorded in the present study.

Characters	<i>S. alba</i>	<i>S. caseolaris</i>	<i>S. griffithii</i>	<i>S. ovata</i>	<i>S. apetala</i>
Leaf shape	obovate to ovate	elliptic to broadly elliptic,	obovate to suborbicular	ovate to orbicular	narrowly elliptic or oblanceolate
Leaf apex	rounded	acute to blunt	rounded	rounded	tapering and blunt
Leaf base	attenuate	attenuate	rounded	rounded	attenuate
Leaf mucronate tip	present folded underside	present folded underside	present folded underside	absent	absent
Colour and texture of bark	smooth grey in young; deeply fissured on maturity	grey or flesh colour, smooth or lightly fissured with thin flakes	pale brown smooth when young and fissured with thick flakes	smooth when young and fissured on maturity with thick flakes	light brown and deeply fissured on maturity with thick flakes
Inflorescence position	terminal or axial	terminal or axial	terminal	terminal	terminal
Number of flowers	1-3 flowered	1-3 flowered	2-7 flowers	1-5 flowered	3-7 flowered
Shape of mature bud	ellipsoidal, broader at base, apex pointed	ellipsoidal, constricted medially and not grooved, apex acute to obtuse	globose, apex obtuse, no medial constriction	oval, apex obtuse	oval, apex acute
Colour of inner side of calyx lobes	often tinged red	green or yellowish white, occasionally tinged red at base	green or yellowish white	often tinged red	yellowish white
Colour and shape of petals	linear, white, occasionally tinged red inside	linear, red	absent	absent	absent
Colour of stamens	numerous, white	numerous, red or white or upper part white and lower part red	numerous, white	numerous, white	numerous, white
Shape and texture of calyx on mature fruit	cup shaped, lobes reflexed towards the fruit stalk, leathery	flat expanded, lobes spreading, leathery	flat expanded, lobes spreading, woody	flat, lobes enveloped the mature fruit, leathery	flat or slightly dome shaped, lobes spreading, leathery
Shape of seed	sickle shaped	angular irregular	angular irregular	angular irregular	angular irregular

by Parkinson (CAL-accession no. 177466) and Kurz (CAL-accession no. 177457) from Andaman Islands (Betapur Creek) and Burma, respectively, are the only specimens that represented *S. griffithii*. There were no specimens of *S. griffithii* at PBL.

Taxonomic treatment

Sonneratia griffithii Kurz (1871, p. 56)

Taxonomic synonyms: *Sonneratia acida* var. *griffithii* King. – *Blatti griffithii* Kuntze.

Description

Tree spreading (Fig. 2A); height to 25 m. Bark pale brown, flaky, smooth when young and fissured at maturity (Fig. 2F). Conical pneumatophores numerous (Fig. 2K), vertical, stout, elongate, cone-shaped, often branching, with soft flaky surface, up to 60 cm long; stem base not buttressed. Leaves simple, opposite, obovate to suborbicular, dark green (Fig. 2B), 7–11 × 6–10 cm with prominent veins on upper side, at apex rounded or emarginate with a mucronate tip (Fig. 2C), cuneate or rounded at base; petiole short, less than 0.5 cm long. Inflorescences solitary cymose on terminal and lateral branches, consisting of 3–5 flowers (Fig. 2D). Mature flower buds globose, 2.5–3.0 cm long, with obtuse apex (Fig. 2D). Calyx tube 3.0–3.5 cm long, widely bell-shaped; calyx lobes 6–7 (Fig. 2H), not enveloping the base of the fruit; inner side of calyx is white (Fig. 2E). Petals absent. Stamens numerous, white, falling off within hours after anthesis (Fig. 2G); anthers yellow, dorsifixed. Ovary multi-locular. Mature fruits berry like, globose with a depressed apex (Fig. 2I), 2.5–3.0 × 4.0–5.5 cm; pericarp leathery; style less persistent (Fig. 2L); persisting calyx lobes spreading (Fig. 2J); seeds numerous, angular (Fig. 2M).

Phenology

Flowering: February to April; fruiting: May to August.

Distribution

Sonneratia griffithii is endemic to the Andaman sea coast and has a scanty distribution in Andaman and Nicobar Islands, Myanmar, Thailand and Malaysia. In Andaman and Nicobar Islands its distribution is restricted to North, Middle and Little Andaman and to confined locations. Betapur Creek in Middle Andaman has well developed plants compared to other locations in the Andaman Islands.

Habitat and ecology

The ecology of *S. griffithii* is not fully known. In the present study it was observed mostly on banks with a mid-estuarine position with soft mud substratum, along with *Xylocarpus moluccensis* (Lam.) M. Roem., *Nypa fruticans* (Thunb.) Wurmb., *Avicennia officinalis* L., *Rhizophora apiculata* Blume and *Excoecaria agallocha* L.

Specimen examined

India, Andaman and Nicobar Islands, Middle Andaman, Betapur Creek (locally also called Dhaninallah Creek; 12°36'55.36"N, 92°57'08.13"E), P. Ragavan, accession no. 103096, 103097 (LWG) and accession no. 30963, 30964 (PBL).

Discussion

Within the genus *Sonneratia*, *S. apetala* is the only species that is easily distinguished from others by its narrowly elliptic leaves, four lobed calyx, umbrella shaped stigma and small fruits (Fig. 3A–E), whereas it is difficult to distinguish the other species based on herbarium specimens without observing the plant in situ (Tomlinson 2016). They can be distinguished from each other in the field based on flowers and fruits characters, particularly flower bud shape, colour of the inside of the calyx, colour of the petals (in buds or young flowers) and the stamens, and the poise of the calyx under mature fruits (Parker 1925, Backer and Van Steenis 1951, Duke and Jackes 1987). Since flowers are nocturnal and short-lived, petals and stamens soon fall off, and it becomes difficult to distinguish *Sonneratia* species without observing the plant while flowering and fruiting. Leaf shape is variable in *Sonneratia* species, and thus it is generally considered less important for specific distinction (Backer and Van Steenis 1951).

Sonneratia griffithii is readily distinguished from other species of *Sonneratia* by its rounded flower bud with obtuse apex, smooth calyx, green or yellowish white inner side of calyx lobes, absence of petals, mature fruit with flat, woody calyx and spreading calyx lobes, short persistent style and angular irregular seeds. In the past *S. griffithii* has often been considered as allied to *S. caseolaris* (Kurz 1877, Clarke 1879, King 1898, Brandis 1906, Troup 1921) probably due to the resemblance in shape of calyx on the mature fruit, green or yellowish white inner side of calyx lobes, angular irregular seeds and to some extent in the bud shape. However, *S. griffithii* is distinct from *S. caseolaris* by its prominent leaf veins, absence of petals, white filaments and hard fruit with short style (Backer and Van Steenis 1951, Aksornkoae et al. 1992). *Sonneratia caseolaris* has obscure leaf veins, ellipsoidal buds, red petals, red or white stamens, and soft fruits with a long style (Fig. 3F–J). To some extent both *S. alba* and *S. griffithii* resemble each other in their leaf shapes, stamen colour and hard fruit, but other flower and fruit characters differ significantly. *Sonneratia alba* differs from *S. griffithii* by its ellipsoidal bud with acute apex, ribbed calyx, presence of linear white petal, red inner side of calyx lobes, mature fruit with cup shaped calyx and reflexed calyx lobes and prominent sickle shaped seeds (Fig. 3K–P). There are also a wide variation in the leaf shape, bud shape and colour of petals and stamens in *S. alba* and *S. caseolaris* (Ragavan 2015, Tomlinson 2016). Though earlier literature regarded *S. griffithii* as allied to *S. caseolaris* and *S. alba*, recent molecular phylogenetic analyses have revealed a closer affinity of *S. griffithii* to *S. apetala*



Figure 2. Morphological features of *Sonneratia griffithii*. (A) from a distance; (B) leaves; (C) recurved mucro; (D) mature buds; (E) opened bud with white stamens; (F) simple stem base and fissured bark; (G) opened flower; (H) Calyx lobes with yellowish inner side (after anthesis); (I and J) mature fruit with flattened calyx with spreading calyx lobes and short style; (K) pneumatophores; (L) young fruit; (M) fruit in cross section.

and *S. ovata* (Yang et al. 2015; Fig. 4). Both *S. griffithii* and *S. ovata* possess suborbicular leaves and apetalous flower with white filaments. However *S. griffithii* differs from *S. ovata* by having a prominent mucronate leaf apex and spreading calyx lobes, whereas leaf tips of *S. ovata* are not mucronate and calyx lobes envelop the fruits (Fig. 3Q–U).

The ecology of *S. griffithii* is still not fully known. However, in the present study it was observed mostly on banks with a mid-estuarine position along with *Xylocarpus moluccensis*, *Nypa fruticans*, *Avicennia officinalis*, *Rhizophora apiculata* and *Excoecaria agallocha*. *Sonneratia alba* was often found in downstream estuarine and low intertidal areas, whereas



Figure 3. Morphological features of *S. apetala* (A–E), *S. caseolaris* (F–J), *S. alba* (K–P) and *S. ovata* (Q–U).

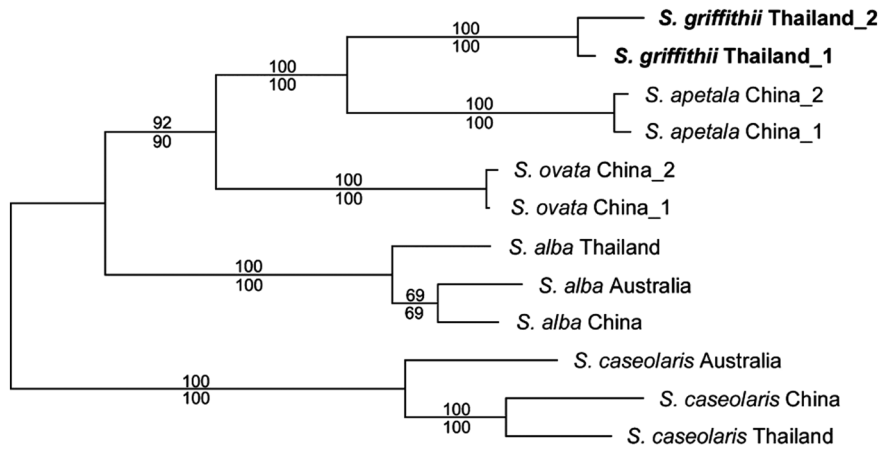


Figure 4. Phylogenetic position of *S. griffithii* (reproduced from Yang et al. 2015).

S. caseolaris was found in areas with upstream estuarine position with freshwater supply. *Sonneratia apetala* and *S. ovata* were found in mid-estuarine and areas of upstream estuarine position having tidal influences, but the former was recorded only on the mainland and the later is restricted to Andaman and Nicobar Islands.

In the past, *S. griffithii* was considered as endemic to Bay of Bengal (Blasco et al. 2001, Blasco and Aizpuru 2002), but the present study prove that it has a restricted distribution also along the Andaman sea coast. Apart from Andaman Islands, *S. griffithii* has been reported from Malaysia, Thailand and Myanmar (Kathiresan and Rajendran 2005, Kathiresan 2010). However the site specific distribution of *S. griffithii* in these countries remains unknown except for a few recent reports from Thailand (Qiu et al. 2008, Yang et al. 2015) and Myanmar (Veettil et al. 2018). *Sonneratia griffithii* have gone locally extinct in several areas within its range (Polidoro et al. 2010). So far no conservation measures specific to this species are in place, largely owing to insufficient data on its occurrence and ecology. Since precise spatial information is imperative for better conservation and management measures, the results of this study should be helpful for revising the global status and distribution of this critically endangered species. Furthermore, the site specific distribution of *S. griffithii* in Andaman Islands presented here will be useful to make immediate conservation measures to increase the population of *S. griffithii* in situ and to study its ecology, reproductive, pollination biology and population genetic structure.

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Supplementary material (online as Appendix njb-02119 at <www.nordicjbotany.org/appendix/njb-02119>). Appendix 1.