The Mangroves of the Southern Islands, Singapore

R.Y. Nicholas Seng, Hui Ping Ang, Geoffrey W. H. Davison, Bryan P. I. Leong, Y. H. Jonathan Tan,

National Parks Board, 1 Cluny Road, 259659 Singapore

ABSTRACT. The mangroves of the Southern Islands form an integral part of the matrix of habitats that connect the biomes of Singapore, and an important interface between terrestrial and marine ecosystems. By filtering silt and sediment, serving as shelter and nurseries for coastal and marine species, and sequestering carbon dioxide and pollutants, mangroves are indispensable for the continued survival of Singapore's biodiversity. While most of the mangrove cover in Singapore has been lost, the remaining Southern Island patches contain an impressive number of mangrove plant species, close to half of all known true mangrove species globally and more than half of known mangrove associate species. This highlights the importance and conservation value of the mangrove fragments found in the Southern Islands. The paper provides an update of existing mangrove plant diversity of the Southern Islands, together with their Singapore Red Data Book (3rd edition) conservation status.

Keywords. Conservation, mangals, mangrove associates, tropics

Introduction

Mangroves are an integral part of Singapore's coastlines and natural heritage (Tan et al., 2010), and once covered about 13% of Singapore's land area, including the tidal stretches of inland waterways, coasts of mainland Singapore, and stretches of the coastlines of the smaller islands (Corlett, 1992; Yee et al., 2010). Most of these have since been cleared for coastal reclamation and construction, beginning when labourers under William Farquhar levelled a hill on the south side of the Singapore River mouth to fill up a mangrove swamp, effectively reclaiming 140 ha of land for port development (Abdullah, 1849; Powell, 2021). After independence in 1965, the Singapore government rapidly expanded coastal land to create space for industrial and housing developments for economic growth. Originally the nation's landmass stood at an estimated 550 km^2 but expanded to about 710 km^2 by 2015 (Lai et al., 2015; Powell, 2021) and is currently about 734 km^2 (Department of Statistics, 2023). This resulted in extensive loss of mangrove forests, sandy beaches, and coral reefs (Lai et al., 2015). However, remnants of mangrove forests persist today, with substantial patches of mangroves fringing various Southern Islands (Yang et al., 2013, Tan et al., 2023).

Despite being not particularly scenic, mangrove forests host a bounty of biodiversity such as mud lobsters, crabs, mudskippers, coastal birds, fish, shrimp, and other species (Tan et al., 2010). They serve as nurseries and shelter for smaller marine creatures seeking refuge from predators in the open sea (Yee et al., 2010) and were once a source of food, timber, thatching, charcoal, dyes, fibre, and traditional medicine for the indigenous Orang Laut community and other early settlers (Ang, 2017). Mangrove products continue to feature in local culture: A native palm, *attap chee* (*Nypa fruticans*), grows in mangroves and its seeds continue to be used in the local desserts *leng chi kang* and *ice kacang* (Tan et al., 2010). The classic Singaporean dish of chilli crab uses mangrove-associated mud crabs (*Scylla* spp.), though nowadays these are imported rather than locally harvested. Besides directly provisioning goods, mangroves provide a wide plethora of ecosystem services; they sequester carbon in their anoxic soils at two to four times the density of mature tropical rain forests, and absorb heavy metals

and other toxic pollutants, reducing their spread into the food web (Friess et al., 2015; Ang, 2017). In addition, they offer coastal protection against wave action and erosion (Yee et al., 2010; Yang et al., 2013), as well as filter sediment from surface runoff which can improve water clarity of surrounding marine ecosystems, assisting with the growth and development of nearby light-dependent coral reefs (Yee et al., 2010). Global estimates suggest that their ecosystem services are worth US$194,000/ha/yr in 2007 price levels, which far outstrips the dollar value of ecosystem services from tropical forests (de Groot et al., 2012).

The flora and fauna of mangroves are adapted to a harsh coastal environment characterised by soft substrate, anaerobic mud, high salinity, continual wave action, repeated inundation and extreme changes in tides. To survive in such conditions, mangrove plants have evolved a range of adaptations such as stilt or prop roots, breathing roots to survive anoxic soils, ultrafiltration, and salt exclusion to maintain water uptake in high salinity, and vivipary to improve rates of survival in offspring (Duke, 2017). The trees' ability to take up water against the osmotic pressure of a highly saline environment is a topic of current research (Kim et al., 2016).

Despite their adaptability and resilience in the intertidal zone, mangroves have a limited geographical range, growing around the tropical region between 30ºN and 30ºS (Tomlinson, 1986). Mangrove fossils from the Latest Cretaceous (about 66 million years ago) have been found in Borneo, suggesting that Southeast Asia might have been a centre of origin for extant mangrove species (Ellison et al., 1999). Mangrove species diversity is markedly higher in the Indo-West Pacific region compared to the Caribbean West Atlantic and other regions, though differences in species distribution are likely due to separate vicariance events rather than point of origin and species dispersal (Ellison et al., 1999; Duke, 2017).

Globally, about 70 plants are considered true mangrove species (Polidoro et al., 2010). Further inland is a coastal plant community of the back mangroves whose component species are termed mangrove associates (Tomlinson, 1986). Distinctions between true mangroves and mangrove associates are debated, but include their physiological parameters such as leaf succulence, salt content and osmotic competence. True mangroves are considered halophytes that can survive the saltwater environment, while associate species have limited salt tolerance (Wang et al., 2009). Turner & Yong (1999) have compiled a checklist of true mangroves and mangrove associate species for Singapore's coastal habitats, and Yang et al. (2013) provided a more up to date checklist of the true mangroves of Singapore in consideration of recent taxonomic changes.

Worldwide, an estimated 1–2% of mangrove forests are lost annually, making way for shrimp farms, tourism, and other coastal developments (Friess & Webb, 2013). In Singapore, losses to mangroves are more drastic, and the changes to Singapore's coastline have led to calls for conservation, restoration and recovery efforts of mangrove species and habitats (Turner & Yong, 1999; Polidoro et al., 2010; Friess & Webb, 2013).

This chapter summarises the mangrove plant diversity of the Southern Islands of Singapore, with separate sections on true mangrove plants and mangrove associates, based on data from published, un-published and SIBS botanical survey data. Site-specific distribution and species richness will be presented along with a discussion of species of interest.

Materials and Methods

Mangrove plant surveys were conducted as part of the terrestrial flora surveys conducted under the Southern Islands Biodiversity Survey (SIBS), between October 2019 and February 2021. Surveyed sites included Pulau Biola, Pulau Hantu, Pulau Sakijang Pelepah (Lazarus Island), Pulau Salu, Pulau Sakijang Bendera (St. John's Island), Pulau Semakau, Sentosa Island (formerly Pulau Blakang Mati) and Pulau Tekukor. Each floral survey lasted for about three hours and was conducted by a team of five to eight participants. Leaf samples of vascular plants were collected, bagged and labelled. The samples were brought to Singapore Botanic Gardens Herbarium (SING) to confirm species identification. Results were collated by the National Biodiversity Centre of NParks into the Southern Islands Flora Database.

Mangrove plant records were also compiled from published literature and NParks' internal records. Published records spanned the period from 1998 to 2019, with full reference details tagged to each record in the flora database. Some of the unpublished records dated from before 1998. Scientific names were standardised according to Lindsay et al. (2022). The addition of literature and herbarium records added five islands to the eight surveyed by the SIBS team.

Basic topographical data on each island and reef (area, maximum elevation, length of coastline) are given by Tan et al. (2025). Miscellaneous information about past settlements and land use of each island is given by Muzaini et al. (2025).

Results

The total numbers of mangrove plants and their associate species recorded at 13 sites in the Southern Islands are shown in Figures 1 and 2, with breakdown by plant family. Altogether, 60 mangrove and mangrove associate species were recorded.

True mangroves

A total of 26 species from 11 taxonomic families of true mangrove plants were recorded, almost 80% of the 34 extant species in Singapore. This is despite the relatively small area of mangrove across all the SIBS sites (which excludes the islands managed by MINDEF). These species occurred at ten of the 13 sites (Figure 1). The most widely recorded species were *Sonneratia alba* and *Xylocarpus granatum*, which were each recorded at eight sites (Table 1). The majority, 23 species, were recorded at between two and seven sites. Two mangrove species and one subspecies were each recorded at only one site; these were *Avicennia marina ssp marina, Dolichandrone spathacea* and *Sonneratia ovata.*

Sites with high mangrove species richness included Pulau Semakau, with 26 true mangrove species, Pulau Sekijang Pelepah with 19 species, Pulau Sekijang Bendera with 18 species, Pulau Blakang Mati with 16 species, and Pulau Subar Laut and Pulau Subar Darat which together had 15 species (Figure 1). The mangroves at Pulau Semakau supported all the true mangrove species recorded in SIBS. Other Southern Island sites had fewer than six recorded true mangrove species, such as Pulau Salu, Pulau Tekukor, Pulau Biola and Pulau Tembakul. The remaining seven SIBS study sites had no true mangrove species.

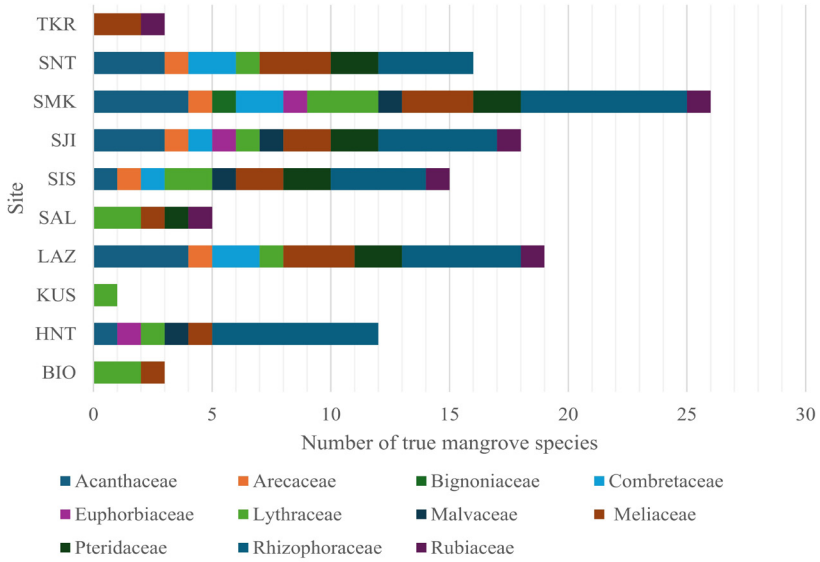

Figure 1. Recorded true mangrove species richness of the Southern Islands, Singapore by site. BIO = Pulau Biola, HNT = Pulau Hantu, KUS = Pulau Tembakul (Kusu Island), LAZ = Pulau Sakijang Pelepah (Lazarus Island) and Pulau Seringat, SAL = Pulau Salu, SIS = Pulau Subar Darat and Pulau Subar Laut (Sisters' Islands), SJI = Pulau Sakijang Benderah (St John's Island), SMK = Pulau Semakau, SNT = Pulau Blakang Mati (Sentosa Island), TKR = Pulau Tekukor.

At national level, six of the true mangrove taxa are currently considered Critically Endangered (CR), seven are Endangered (EN), three are Vulnerable (VU) and 12 are of Least Concern (LC) (Davison et al., 2024). With more than half of the Southern Island's mangrove species under threat, the remnants of mangroves in the Southern Islands are nationally of high conservation value. Pulau Semakau has further conservation interest as it has nearly all the recorded true mangrove species of the Southern Islands.

Mangrove associates

There were 32 species of mangrove associates recorded from the Southern Islands (Table 2). Mangrove associates were recorded at 13 sites, compared with ten sites for true mangrove species. The most widely recorded species were *Casuarina equisetifolia*, *Calophyllum inophyllum*, *Terminalia catappa*, *Scaevola taccada*, *Hibiscus tiliaceus* and *Planchonella obovata*, which were each recorded at 11 sites (Table 2). The remaining associate species were recorded at one to eight sites each, the least widely recorded species being *Calamus erinaceus*, *Aganope heptaphylla*, *Derris scandens*, *Intsia bijuga*, *Glochidion littorale* and *Myrsine capitellata* each recorded at only one site.

The sites with the highest mangrove associate species diversity included Pulau Subar Darat and Pulau Subar Laut (Sisters' Islands), and Pulau Semakau, both with 25 species recorded, Pulau Blakang Mati (Sentosa) with 23 associate species, and Pulau Sekijang Bendera (St John's Island) with 19 associate species. Four SIBS survey sites had no mangrove associates: three of these (Pulau Berkas, Terumbu Pandan [Cyrene Reef] and the Terumbu Pempang reefs) were reefs with no land available, and one (Pulau Satumu [Raffles Lighthouse]) lacked suitable habitat.

Figure 2. Recorded mangrove associate species richness of the Southern Islands, Singapore by site. BIO = Pulau Biola, BRN = Pulau Brani, HNT = Pulau Hantu, JNG = Pulau Jong, KEP = Keppel Island, KUS = Pulau Tembakul (Kusu Island), LAZ = Pulau Sekijang Pelepah (Lazarus Island), SAL = Pulau Salu, SIS = Pulau Subar Darat and Pulau Subar Laut (Sisters' Islands), SJI = Pulau Sekijang Benderah (St John's Island), SMK = Pulau Semakau, SNT = Pulau Blakang Mati (Sentosa Island), TKR = Pulau Tekukor.

The recorded mangrove associate species included five Critically Endangered (CR), six Endangered (EN), one Vulnerable (VU), 18 species of Least Concern and two species not assessed at national level (Davison et al., 2024). Thus, a total of 12 mangrove associate species are nationally of conservation interest.

Across 14 sites there was a moderate correlation between the number of true mangrove species and the number of mangrove associates (Spearman Rank $\chi^2 = 0.7225$, $n=14$, $\Sigma d^2 = 126.25$, $p<0.05$), but where true mangroves had been eliminated some mangrove associates had either managed to linger on or to recolonise (e.g., Pulau Brani, Keppel Island). Total mangrove species richness (true mangrove species plus associates) was not significantly correlated with length of coastline of the respective islands (Spearman Rank $\chi^2 = 0.3593$, $n=14$, $\Sigma d^2 = 163.5$, $p>0.05$) but this was attributable to two outliers in the data (Sisters Islands and Pulau Brani), both of which have a large proportion of masonry revetment along their coasts.

Table 1. Locations of true mangrove taxa found in Southern Islands from published and unpublished literature and Southern Islands Biodiversity Survey (SIBS) data. SIBS indicates taxa was observed during Southern Islands Biodiversity Survey 2019-2022. Year indicates latest literature with taxa observation. RDB3 = Singapore Red Data Book 3 Status, IUCN = International Union for Conservation of Nature Status, BIO = Pulau Biola, HNT = Pulau Hantu, KUS = Pulau Tembakul (Kusu Island), LAZ = Pulau Sekijang Pelepah (Lazarus Island), SAL = Pulau Salu, SIS = Pulau Subar Darat and Pulau Subar Laut (Sisters' Islands), SJI = Pulau Sekijang Benderah (St John's Island), SMK = Pulau Semakau, SNT = Pulau Blakang Mati (Sentosa Island), TKR = Pulau Tekukor. Acronyms for RDB3/IUCN: EX = Globally Extinct, NE = Presumed Nationally Extinct, CR = Critically Endangered, EN = Endangered, VU = Vulnerable, NT = Near Threatened, LC = Least Concern, DD = Data Deficient, NE = Not Evaluated, NA = Not Assessed.

Taxa*	**RDB3**	**IUCN**	**BIO**	**HNT**	**KUS**	**LAZ**	**SAL**	**SIS**	**SJI**	**SMK**	**SNT**	**TKR**
Family Acanthaceae												
Avicennia alba	LC	LC				SIBS; 2018			1998	SIBS; 2012	SIBS	
Avicennia marina	CR	NE				SIBS; 2018		2015	(1)	SIBS; 2012	SIBS	
Avicennia officinalis	LC	LC				SIBS; 2018				2012		
Avicennia rumphiana	LC	NE		SIBS		SIBS; 2018			(1)	SIBS; 2012	SIBS	
Family Arecaceae												
Nypa fruticans	VU	NE				2018		2015	SIBS; 2010	SIBS; 2012	SIBS	
Family Bignoniaceae												
Dolichandrone spathacea	CR	LC								SIBS; 2012		
Family Combretaceae												
Lumnitzera littorea	EN	NE				2018		2015	1998	SIBS; 2012	SIBS	
Lumnitzera racemosa	EN	NE				SIBS; 2018				SIBS; 2012	SIBS	

(1): SING Herbarium record; it is now absent on Kusu, (2): Unpublished data,*: True mangrove species list sieved from SIBS flora database using Singapore mangrove species list from Yang et al., 2013.

Table 1 continued. Locations of true mangrove taxa found in Southern Island waters from published and unpublished literature and Southern Islands Biodiversity Survey (SIBS) data. SIBS indicates taxa was observed during Southern Islands Biodiversity Survey 2019-2022. Year indicates latest literature with taxa observation.

Taxa*	RDB3	IUCN	BIO	HNT	KUS	LAZ	SAL	SIS	SJI	SMK	SNT	TKR
Family Euphorbiaceae												
Excoecaria agallocha	LC	NE		SIBS; 2001					SIBS; (2)	SIBS; 2012		
Family Lythraceae												
Pemphis acidula	CR	NE	SIBS; 2007		(1)		SIBS	2019		2012		
Sonneratia alba	LC	NE	SIBS	SIBS; 2001		SIBS; 2018	SIBS	2015	1998	SIBS; 2012	SIBS	
Sonneratia ovata	CR	NT								2005		
Family Malvaceae												
Heritiera littoralis	EN	NE		(1)				2015	2017	SIBS; 2012		
Family Meliaceae												
Xylocarpus granatum	LC	NE	SIBS	SIBS; 2001		SIBS		2019	SIBS; 2017	SIBS; 2012	SIBS; 2018	SIBS; 2017
Xylocarpus moluccensis	EN	LC				2018				2012	SIBS	
Xylocarpus rumphii	CR	NE				SIBS	SIBS	2015	2017	2012	SIBS; 2018	2015
Family Pteridaceae												
Acrostichum aureum	LC	NE				SIBS		2015	SIBS; 2017	SIBS; 2012	SIBS	
Acrostichum speciosum	LC	LC				2003	SIBS	2015	SIBS; 1998	2012	2018	

(1): SING Herbarium record; it is now absent on Kusu, (2): Unpublished data,*: True mangrove species list sieved from SIBS flora database using Singapore mangrove species list from Yang et al., 2013.

Table 1 continued. Locations of true mangrove taxa found in Southern Island waters from published and unpublished literature and Southern Islands Biodiversity Survey (SIBS) data. SIBS indicates taxa was observed during Southern Islands Biodiversity Survey 2019-2022. Year indicates latest literature with taxa observation.

Taxa*	RDB3	IUCN	BIO	HNT	KUS	LAZ	SAL	SIS	SJI	SMK	SNT	TKR
Family Rhizophoraceae												
Bruguiera cylindrica	LC	LC		SIBS		SIBS; 2018			(2)	SIBS; 2012	SIBS	
Bruguiera gymnorhiza	LC	NE		SIBS		SIBS; 2018		2015	2017	SIBS; 2012	SIBS	
Family Rhizophoraceae												
Ceriops tagal	VU	NE		SIBS						SIBS; 2012		
Ceriops zippeliana	EN	NE		SIBS		SIBS				2012		
Rhizophora apiculata	LC	NE		2001		SIBS; 2018		2015	SIBS; 1998	SIBS; 2012	SIBS	
Rhizophora mucronata	LC	NE		SIBS		SIBS; 2018		2015	2017	SIBS; 2012		
Rhizophora stylosa	VU	NE		SIBS				2019	2017	SIBS; 2012	SIBS	
Family Rubiaceae												
Scyphiphora hydrophylacea	EN	LC				SIBS	SIBS	SIBS; 2019	SIBS; 1998	SIBS; 2012		SIBS; 2017

*True mangrove species list sieved from SIBS flora database using Singapore mangrove species list from Yang et al., 2013.

Table 2. Locations of mangrove associate taxa found in Southern Islands from published and unpublished literature and Southern Islands Biodiversity Survey (SIBS) data. SIBS indicates taxa was observed during Southern Islands Biodiversity Survey 2019-2022. Year indicates latest literature with taxa observation. RDB3 = Singapore Red Data Book 3 Status, IUCN = International Union for Conservation of Nature Status, BIO = Pulau Biola, BRN = Pulau Brani, HNT = Pulau Hantu, JNG = Pulau Jong, KEP = Keppel Island, KUS = Pulau Tembakul (Kusu Island), LAZ = Pulau Sekijang Pelepah (Lazarus Island), SAL = Pulau Salu, SIS = Pulau Subar Darat and Pulau Subar Laut (Sisters' Islands), SJI = Pulau Sekijang Benderah (St John's Island), SMK = Pulau Semakau, SNT = Pulau Blakang Mati (Sentosa Island), TKR = Pulau Tekukor. Acronyms for RDB3/IUCN: EX = Globally Extinct, NE = Presumed Nationally Extinct, CR = Critically Endangered, EN = Endangered, VU = Vulnerable, NT = Near Threatened, LC = Least Concern, DD = Data Deficient, NE = Not Evaluated, NA = Not Assessed.

Taxa*	RDB3	IUCN	BIO	BRN	HNT	JNG	KEP	KUS	LAZ	SAL	SIS	SJI	SMK	SNT	TKR
Family Aizoaceae															
Sesuvium portulacastrum	LC	LC			SIBS; 2002			SIBS; (1)	SIBS; 2018		SIBS; 2019		SIBS; 2012	SIBS	
Family Amaryllidaceae															
Crinum asiaticum	CR	NE			SIBS		2016	SIBS			2019		2012	SIBS; 2018	
Family Anacardiaceae															
Buchanania arborescens	LC	LC		SIBS; 2018			SIBS; 2016	SIBS; 2002	SIBS; 2018		2019	SIBS; 2017		SIBS; 2018	SIBS; 2017
Family Apocynaceae															
Cerbera manghas	CR	LC			2001						2015	SIBS; 2017	2012		
Cerbera odollam	VU	LC					2016	SIBS	2018		2019	2017	SIBS; 2012	SIBS; 2018	
Family Arecaceae															
Calamus erinaceus	LC	NE											SIBS; 2012		
Oncosperma tigillarium	LC	NE				SIBS	2016				2019			SIBS; 2018	SIBS; 2017

(1): Unpublished data, *: Mangrove associate species list sieved from SIBS flora database using mangrove transition species list from Turner & Yong, 1999.

Table 2 continued. Locations of mangrove associate taxa found in Southern Island waters from published and unpublished literature and Southern Islands Biodiversity Survey (SIBS) data. SIBS indicates taxa was observed during Southern Islands Biodiversity Survey 2019-2022. Year indicates latest literature with taxa observation.

Taxa*	RDB3	IUCN	BIO	BRN	HNT	JNG	KEP	KUS	LAZ	SAL	SIS	SJI	SMK	SNT	TKR
Family Casuarinaceae															
Casuarina equisetifolia	LC	LC	SIBS; 2002	2018	SIBS; 2001		2016	SIBS; 2010	SIBS; 2018		SIBS; 2019	SIBS; 2017	SIBS; 2012	SIBS	SIBS; 2017
Family Clusiaceae															
Calophyllum inophyllum	EN	LC		2018	SIBS; 2002		2016	SIBS; 2002	SIBS; 2018	SIBS	2019	SIBS; 2017	SIBS; 2012	SIBS; 2010	SIBS; 2017
Family Combretaceae															
Terminalia catappa	LC	LC	SIBS	SIBS; 2018	SIBS; 2002			SIBS; 2010	SIBS; 2018	SIBS	2019	SIBS; 2017	SIBS; 2012	SIBS; 2018	SIBS; 2017
Family Fabaceae															
Aganope heptaphylla	CR	NE											2012		
Caesalpinia crista	LC	NE							SIBS; 2018		2015		SIBS; 2012	SIBS; 2010	2015
Dalbergia candenatensis	LC	LC			SIBS	SIBS; (1)					SIBS; 2019	2017	SIBS; 2012		
Derris scandens	NA	LC											SIBS; 2012		
Derris trifoliata	LC	NE			SIBS; 2002	SIBS			SIBS; 2018	SIBS	2019	SIBS; 2017	SIBS; 2012	SIBS; 2018	
Intsia bijuga	CR	NT				(1)									
Millettia (Pongamia) pinnata	EN	LC			SIBS; 2001	SIBS		SIBS	SIBS; 2018		2019	(1)	SIBS; 2012	SIBS; 2018	

(1): SING Herbarium record; it is now absent on Kusu, (2): Unpublished data,*: True mangrove species list sieved from SIBS flora database using Singapore mangrove species list from Yang et al., 2013.

Table 2 continued. Locations of mangrove associate taxa found in Southern Island waters from published and unpublished literature and Southern Islands Biodiversity Survey (SIBS) data. SIBS indicates taxa was observed during Southern Islands Biodiversity Survey 2019-2022. Year indicates latest literature with taxa observation.

Taxa*	RDB3	IUCN	BIO	BRN	HNT	JNG	KEP	KUS	LAZ	SAL	SIS	SJI	SMK	SNT	TKR
Family Flagellariaceae															
Flagellaria indica	LC	NE		2018	SIBS; 2002								SIBS; 2012	SIBS	
Family Goodeniaceae															
Scaevola taccada	LC	NE	SIBS		SIBS; 2002	SIBS	2016		SIBS; 2018	SIBS; (1)	2019	2017	SIBS; 2012	SIBS; 2018	
Family Lamiaceae															
Volkameria inermis	LC	NE	SIBS		SIBS; 2001				SIBS		2019	2017	2012	SIBS; 2018	
Family Lecythidaceae															
Barringtonia asiatica	CR	LC			SIBS			SIBS; (1)	SIBS; 2018		2019	SIBS	SIBS; 2012	SIBS; 2018	
Family Malpighiaceae															
Tristellateia australasiae	EN	NE						SIBS						SIBS	
Family Malvaceae															
Hibiscus tiliaceus	LC	LC			SIBS; 2002	SIBS	SIBS	SIBS	SIBS; 2018	SIBS	2019	SIBS; 2017	SIBS; 2012	SIBS; 2018	
Thespesia populnea	LC	LC			2001	SIBS			SIBS	SIBS	2019	2017	SIBS; 2012		
Family Pandanaceae															
Pandanus tectorius	NA	LC					2016				2015		2002	2018	
Family Phyllanthaceae															
Breynia racemosa	LC	LC									2015	2017	2012	SIBS; 2010	

(1): SING Herbarium record; it is now absent on Kusu, (2): Unpublished data,*: True mangrove species list sieved from SIBS flora database using Singapore mangrove species list from Yang et al., 2013.

Table 2 continued. Locations of mangrove associate taxa found in Southern Island waters from published and unpublished literature and Southern Islands Biodiversity Survey (SIBS) data. SIBS indicates taxa was observed during Southern Islands Biodiversity Survey 2019-2022. Year indicates latest literature with taxa observation.

Taxa*	RDB3	IUCN	BIO	BRN	HNT	JNG	KEP	KUS	LAZ	SAL	SIS	SJI	SMK	SNT	TKR
Family Phyllanthaceae															
Glochidion littorale	EN	LC												2001	
Family Podocarpaceae															
Podocarpus polystachyus	EN	VU				SIBS; (1)			SIBS; 2018		SIBS; 2019	SIBS; 2017		SIBS; 2018	
Family Primulaceae															
Ardisia elliptica	LC	NE		2018	2001						2019	SIBS; 2017	SIBS; 2012	SIBS; 2018	
Myrsine capitellata	EN	NE									SIBS				
Family Sapindaceae															
Allophylus cobbe	LC	NE									2015	(1)	SIBS; 2012		
Family Sapotaceae															
Planchonella obovata	LC	NE	SIBS	SIBS; 2018			SIBS; 2016	SIBS	SIBS; 2018	SIBS	2019	SIBS; 2017	2012	SIBS; 2018	SIBS; 2017

(1): Unpublished data, *: Mangrove associate species list sieved from SIBS flora database using mangrove transition species list from Turner & Yong, 1999.

Discussion

With about 70 true mangrove species globally (Polidoro et al., 2010), Singapore is home to half of all known mangrove species (Yang et al., 2013). Of these, 26 taxa of true mangroves are found in the Southern Islands. Many of the recorded species are of conservation concern at the national level, which signals the importance of these remnant patches to Singapore's botanical diversity.

Likewise, Singapore is home to a substantial number of mangrove associate species. Tomlinson (1986) estimated that there are about 60 mangrove associate species from 46 genera globally. Turner & Yong (1999) and Yang et al. (2013) listed about 40 mangrove associate species in Singapore, not necessarily using the same criteria as Tomlinson (1986). It is nevertheless a substantial proportion of the global total. In the Southern Islands, 32 of Singapore's 40 mangrove associates have been recorded, which is more than three quarters of all species nationally.

Pulau Semakau is viewed primarily as Singapore's offshore landfill site for waste disposal, but it has the highest true mangrove and mangrove associate species richness out of all the sites surveyed in the Southern Islands Biodiversity Survey. The importance of mangroves on Pulau Semakau was already recognized prior to its use for landfill, and the replanting of mangroves was one of the conditions of use (Chou, 2011). Although some mangroves were lost during construction, tracts of mangroves were replanted within inlets between the remaining natural mangroves and the periphery of the landfill (Teo et al., 2011). The replanted tracts of mangroves now persist alongside the natural mangroves.

Other sites with surprisingly high true mangrove species richness, such as Pulau Sekijang Pelepah (Lazarus Island) and Pulau Sekijang Bendera (St John's Island), have a mangrove cover of about 0.1 hectares (Yang et al., 2013). This is much lower forest coverage than Pulau Semakau, which has about 39 hectares of mangrove forest. Maintaining this pocket of mangrove forest on the Pulau Sekijang cluster, however small, is still of conservation interest due to the presence of endangered species such as *Avicennia marina*, *Nypa fruticans* and *Rhizophora stylosa*. Maintaining mangrove fragments on as many islands as possible is important in (a) spreading risks of loss from causes such as sea level rise, oil spill or plant diseases, (b) retaining as much genetic diversity as possible, and (c) providing reservoirs for seed dispersal and recolonization of other sites. No one site had all species, so the full floristic diversity can only be maintained by the network of sites spread across many islands.

Of interest is the widespread distribution of the critically endangered *Pemphis acidula* (recorded recently from four sites), which is now extinct on mainland Singapore (though recorded on Pulau Ubin by Yang et al., (2013)). This tree has a unique form resembling bonsai, with gnarled, twisted trunks and roots that cling to exposed rocky shores. Its absence on the mainland is likely due to the loss of natural rocky shore habitats, which are now found only in tiny stretches such as Labrador Nature Reserve and the Western Water Catchment. This species thus illustrates the importance of the Southern Islands as a refugia for habitats and species that are otherwise lost on mainland Singapore.

Three Southern Islands survey sites had mangrove associate species but lacked true mangrove species. These sites are Pulau Brani, Pulau Jong and Keppel Island. The lack of suitable habitat for true mangroves on Pulau Brani and Keppel is attributable to urbanization and development. Pulau Brani was developed into a Naval Base in the 1960s, and subsequently redeveloped into Police Coast Guard Headquarters in 2006 (National Heritage Board, 2023).

Keppel Island was once used as a jetty and for shipping repairs and has since been developed into a marina for yachts, restaurants, and high-end housing complexes (Marina Keppel Bay, 2014). Strong wave action and currents at Pulau Jong (PADI, 2023), as well as a narrow rocky coastline and high ship traffic, have made it difficult for true mangrove plants to establish around Pulau Jong.

The mangroves and mangrove associates of the Southern Islands of Singapore are indispensable for the survival of Singapore's full biodiversity. Their proximity to the Southern Island reefs signals their importance in maintaining habitat connectivity through the marine ecosystem, particularly for marine species such as fish and crustaceans, including for artisanal fisheries and for marine aquaculture. With their ability to filter and retain silt, mangroves can be important in coastal protection and in providing nature-based solutions to sea level rise.

ACKNOWLEDGEMENTS. Surveys were conducted by staff of the National Biodiversity Centre and Pasir Panjang Nursery, National Parks Board. We express our heartfelt gratitude to the many volunteers and experts who have generously supported the SIBS survey with their time and efforts, through compiling data, conducting surveys, and providing guidance on species identification, without which this report would not have been possible. A full list of those acknowledged for supporting and taking part in the Southern Islands Biodiversity Survey is given by Tan et al. (2025).

References

Abdullah bin Abdul al Kadir (Munshi Abdullah) (1849). *The Autobiography of Munshi Abdullah*. (Transl. W.G. Shellabear). Singapore: Methodist Publishing House, 1918.

Ang, S.L. (2017, April 9). *Mangroves: A tale of survival*. NLB BiblioAsia. https://biblioasia.nlb.gov.sg/vol-13/issue-1/apr-jun-2017/mangroves/

Chou, L.M. (2011). Coastal Ecosystems. In P.K.L. Ng, R. Corlett, & H.T.W. Tan (eds.), *Singapore biodiversity: An encyclopedia of the natural environment and sustainable development* (pp. 67–68). Singapore: Editions Didier Millet.

Corlett, R.T. (1992). The ecological transformation of Singapore, 1819–1990. *Journal of Biogeography*, *19*(4), 411. https://doi.org/10.2307/2845569

Davison, G.W.H., Gan, J.W.M., Huang, D., Hwang, W.S., Lum, S.K.Y. & Yeo, D.C.J. (eds.) (2024). *The Singapore Red Data Book: Red Lists of Singapore Biodiversity*. Third edition. National Parks Board, Singapore. Pp. xx + 688.

Department of Statistics (2023). Environment. https://www.singstat.gov.sg/find-data/search-by-theme/society/environment/latest-data. Retrieved 3 August 2023.

de Groot, R., Brander, R., van der Ploeg, S., Costanza, R., Bernard, F., Braat, L., Christie, M., Crossman, N., Ghermandi, A., Hein, L., Hussain, S., Kumar, P., McVittie, A., Portela, R., Rodriguez, L.C., ten Brink, P. & van Beukering, P. (2012) Global estimates of the value of ecosystems and their services in monetary units. *Ecosystem Services* 1: 50–61.

Duke, N.C. (2017). Mangrove Floristics and Biogeography Revisited: Further Deductions from Biodiversity Hot Spots, Ancestral Discontinuities, and Common Evolutionary Processes. In *Productivity and Carbon Dynamics in Mangrove Wetlands* (pp. 17–53). Springer.

Ellison, A.M., Farnsworth, E.J. & Merkt, R.E. (1999). Origins of mangrove ecosystems and the mangrove biodiversity anomaly. *Global Ecology and Biogeography* 8: 95–115.

Friess, D.A., Richards, D.R. & Phang, V.X. (2015). Mangrove forests store high densities of carbon across the tropical urban landscape of Singapore. *Urban Ecosystems* 19: 795–810.

Friess, D.A. & Webb, E.L. (2013). Variability in mangrove change estimates and implications for the assessment of ecosystem service provision. *Global Ecology and Biogeography* 23*:* 715–725.

Lai, S., Loke, L.H., Hilton, M.J., Bouma, T.J. & Todd, P.A. (2015). The effects of urbanisation on coastal habitats and the potential for ecological engineering: A Singapore case study. *Ocean and Coastal Management* 103: 78–85.

Lindsay, S., Middleton, D.J., Ho, B.C., Chong, K.Y., Turner, I.M., Ali Ibrahim, Alonso-García, M., Ang, W.F., Ashton, P.S., Athen, P., Atkins, S., Bazilah Ibrahim, Beentje, H.J., Boo, C.M., Boyce, P.C., Bramley,

G.L.C., Buerki, S., Callmander, M.W., Chantanaorrapint, S., Cheek, M., Chen, C.-W., Chen, J., Chen, L.M.J., Chew, P.T., Chong, R., Choo, L.M., Chung, R.C.K., Coode, M.J.E., Chua, S.C., Cicuzza, D., de Kok, R.P.J., Davison, G.W.H., de Wilde, W.J.J.O., Duistermaat, H., Dubéarnès, A., Duyfjes, B.E.E., Ellis, L.T., Esser, H.-J., Gajurel, P.R., Gale, S.W., Ganesan, S.K., Gardner, E.M., Geiger, D.L., Harwood, R.K., Hassan Ibrahim, He, S., Henderson, A., Hovenkamp, P.H., Hughes, M., Zaki Jamil, Jebb, M.H.P., Johnson, D.M., Kartonegoro, A., Kiew, R., Knapp, S., Koh, S.L., Kurzweil, H., Lee, S., Leong, P.K.F., Leong-Škorničková, J., Levin, G.A., Liew, D.C.H., Lim, R.C.J., Lim, W.H., Loo, A.H.B., Low, Y.W., Lua, H.K., Lum, S., Mabberley, D.J., Mahyuni, R., Maslin, B., Murray, N.A., Neo, L., Ng, X.Y., Ngo, K.M., Niissalo, M.A., Ong, P.T., Pannell, C.M., Phang, A., Prance, G.T., Promma, C., Puglisi, C., Rodda, M.L., Rubasinghe, S.C.K., Saunders, R.M.K., Savinov, I.A., Saw, L.G., Schuiteman, A., Seah, W.W., Simpson, D.A., Strijk, J.S., Sukkharak, P., Sugumaran, M., Syahida-Emiza, S., Tan, J.P.C., Taylor, N.P., Teo, Y.K.L., Thomas, D.C., Trias-Blasi, A., Utteridge, T., van Welzen, P.C., Veldkamp, J.F., Vermeulen, J., Wang, R., Wilkie, P., Wei, Y.-M., Wong, S.Y., Wong, K.M., Yaakub, S., Yam, T.W., Yang, S., Yao, T.L., Ye, W., Yee, A.T.K., Yeo, C.K., Yeoh, Y.S., Yong, C., Yong, K.T., Zerega, N.J.C., Zhu, R.-L., Er, K.B.H. (2022). Flora of Singapore: Checklist and bibliography. Gardens' Bulletin Singapore 74 (Suppl.1): 3–860. https://doi.org/10.26492/gbs74(suppl.1).2022-01

Marina Keppel Bay (2014, April 22). Marina Keppel Bay - Vibrant waterfront lifestyle experiences. https://marinakeppelbay.com/

National Heritage Board (2023). *Pulau Brani*. Roots. https://www.roots.gov.sg/Collection-Landing/listing/1261301

PADI. (2023). *Pulau Jong dive site | PADI*. PADI Travel. https://www.padi.com/dive-site/singapore/pulau-jong/

Polidoro, B.A., Carpenter, K.E., Collins, L., Duke, N.C., Ellison, A.M., Ellison, J.C., Farnsworth, E.J., Fernando, E.S., Kathiresan, K., Koedam, N.E., Livingstone, S.R., Miyagi, T., Moore, G.E., Ngoc Nam, V., Ong, J.E., Primavera, J.H., Salmo, S.G., Sanciangco, J.C., Sukardjo, S., … Yong, J.W. (2010). The loss of species: Mangrove extinction risk and geographic areas of global concern. *PLoS ONE 5*(4). https://doi.org/10.1371/journal.pone.0010095

Powell, M.A. (2021). Singapore's lost coast: Land reclamation, national development and the erasure of human and ecological communities, 1822–Present. *Environment and History 27*(4), 635–663.

Tan, H.T.W., Chou, L.M., Yeo, D.C. & Ng, P.K.L. (2010). *The natural heritage of Singapore* (3rd ed.). Singapore: Pearson.

Tan, Y.H.J., Leong, B.P.I., Davison, G.W.H. & Tun, K.P.P. (2025). Introduction to the Southern Islands Biodiversity Survey, Singapore, 2020–2022. In Davison, G.W.H., Leong, B.P.I., Tan, Y.H.J., Seng, R.Y.N. & Mark, R.Y.Y, *The Southern Islands Biodiversity Survey, Singapore.* National Parks Board, Singapore. https://go.gov.sg/sibs-introduction

Tan, Y.H.J., Tham, J.K.Q., Paul, A., Rana, U., Ang, H.P., Nguyen, N.T.H., Yee, A.T.K., Leong, B.P.I., Drummond, S. & Tun, K.P.P. (2023) Remote sensing mapping of the regeneration of coastal natural habitats in Singapore: Implications for marine conservation in tropical cities. S*ingapore Journal of Tropical Geography* 44(1): 130–148.

Teo, S., Yeo, R.K.H., Chong, K.Y., Chung, Y.F., Neo, L. & Tan, H.T.W. (2011). The Flora of Pulau Semakau: A Project Semakau Checklist. *Nature in Singapore* 4*:* 263–272.

Tomlinson, P.B. (1986). *The botany of mangroves*. Cambridge, UK: Cambridge University Press.

Turner, I.M. & Yong, J.W.H. (1999). The coastal vegetation of Singapore. *State of the Natural Environment Singapore*, 5–23.

Yang, S., Lim, R.L., Sheue, C. & Yong, J.W.H. (2013). The current status of mangrove forests in Singapore. *Proceedings of Nature Society, Singapore's Conference on "Nature Conservation for a Sustainable Singapore"*: 99–120.

Yee, A.T., Ang, W.F., Teo, S., Liew, S.C. & Tan, H.T.W. (2010). The present extent of the mangrove forests in Singapore. *Nature in Singapore* 3: 139–145.