1. INTRODUCTION

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The *Flora of Singapore* is a project to catalogue and describe the diversity of all families, genera and species (and occasionally infraspecific taxa) of bryophytes, lycophytes, ferns, gymnosperms and angiosperms that are native, naturalised, casual or cryptogenic in Singapore. When the project is completed, the *Flora* will include identification keys and descriptions for all of the more than 3000 species in Singapore along with other useful information about the plants. We are taking a semi-monographic approach, which is to say that the accounts will be based on thorough and original taxonomic research. We also want the *Flora* to be visually appealing and easy to use by having many line drawings along with even more copious colour photographs. Volume 1, which is the Introduction to the entire project, and volumes 7 and 13, the Poales and Gentianales respectively, were published in 2019 (Middleton et al., 2019a, 2019b, 2019c). Volume 4, which includes the gymnosperms and basal angiosperms, was published in 2026 (Middleton et al., 2026). Volume 1 is already out of print and we have, therefore, taken this opportunity to update the introductory chapters in a second edition rather than to reprint the first edition.

Each plant family has been pre-assigned to a volume arranged taxonomically according to recent standards in each major plant group. The taxonomic structure being used is presented in Chapter 2. This has the effect of ensuring that related families are treated together. Since the first edition was published, ongoing taxonomic and phylogenetic work has led to greater insights into the plant diversity of Singapore which is reflected in adjustments to the taxonomic structure being used across the remaining volumes.

The format of the *Flora of Singapore* is broadly similar to that of the *Flora of Peninsular Malaysia* which is itself similar to *Flora Malesiana*. For each account the following details will be presented: family description; key to genera; descriptions of the genera; key to the species in each genus; detailed nomenclatural information for each species including synonyms and types; a description of each species (and infraspecific taxa when present); distribution of the species, globally and within Singapore (with up to five specimens from Singapore being cited to enable future verification of the species concepts being used); ecology of the species; an IUCN conservation assessment of each species on the global and national level; uses when relevant; vernacular name(s) as documented by NParks' Flora & Fauna Web; and notes to explain taxonomic or other issues.

The *Flora of Singapore* includes all native, naturalised, casual and cryptogenic species. Native species are those that occur in Singapore naturally. Naturalised species are those that were initially brought to Singapore due to human activity, intentionally or unintentionally, and have since escaped into the wild and formed self-sustaining populations. Sometimes species which were formerly naturalised or casual in Singapore have since ceased to be so, possibly due to changing land use. Casual species are those that escape from cultivation but do not

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form self-sustaining populations. The distinction between a naturalised and casual species can be rather subjective and whether a species is one or the other can change over time. A slight variation on the category of casual species is that we are also including species that may well have been originally planted but which are known to persist long after a site has been abandoned and has returned to forest. The distinction between these and cultivated species, which we are not including in the *Flora*, is, of course, rather subjective and has been left to the discretion of each author. Generally, in cases where there may be doubt as to whether a taxon should be included or not, we are erring on the side of inclusion. Our intention is that any plant that is found in the wild and which an observer may come upon without knowing whether it is native or introduced, should be included in the *Flora*.

Even for native species, it is not always straightforward to decide whether a species is native or not. Chong et al. (2009) assigned over 200 species in Singapore to a category of 'weeds of uncertain origin', hereafter referred to as 'cryptogenic' species. These are particularly prevalent in families such as Acanthaceae, Asteraceae, Lentibulariaceae, Linderniaceae and Poaceae. Many of these are likely to have an exotic origin and are only in Singapore due to the very high level of disturbance and the plants having arrived through human agency. But the majority of them are native in the region and could be treated as native except for the fact that before widespread agriculture and deforestation there would have been very little opportunity for them to establish in the open areas they require. But even without forest clearance by humans, there could have been periods of more open areas created through fire or large tree falls when such species could have come and gone depending on their ability to colonise over large distances.

The inclusion of species in the *Flora of Singapore* is based on verified records of the species occurring in Singapore. The most reliable way to confirm these records is in the form of herbarium specimens. Many of the very early collections give no further locality information than 'Singapore'. From the later nineteenth century onwards the locality information given on specimen labels began to be somewhat more detailed. In Singapore, as everywhere in the world, older place names can often be difficult to precisely georeference but this has been greatly aided by Chen et al. (2014). The specimens from Singapore form a permanent record of the species that can be studied and confirmed in the future, along with the localities where the specimens were collected. One insurmountable problem with this is that although a small number of specimens were collected when Singapore was still covered in its native vegetation, by the time that concerted collecting began in the late nineteenth century, most of the forest had already been destroyed (Barnard, 2016). Indeed, there are contemporary reports of species already having been lost in the 1870s, before the likelihood of any collections being made (Barnard, 2016). Early Superintendents and Directors of Singapore Botanic Gardens such as Henry Murton, Nathaniel Cantley and Henry Ridley had varying degrees of responsibility for forest conservation in Singapore, or rather forest productivity that required that there be forest in the first place. They had to do this work against the background of intransigent, sometimes even hostile, colonial officials (Barnard, 2016). These botanists were acutely aware of what was being very rapidly lost and the need to catalogue and conserve it. But even they began their work after most of the original forest cover of Singapore was already lost. In some accounts for the *Flora of Singapore*, therefore, authors will speculate that a species not known from Singapore must nevertheless have been in the country before such forest loss.

With the various caveats expressed above, Table 1 presents a summary of approximate numbers of species and taxa (i.e., inclusive of infraspecific taxa present in Singapore) in the

Table 1. Current numbers of native, non-native (i.e., naturalised or casual) and cryptogenic (i.e., status uncertain) species and taxa for each major plant group in Singapore. The number of taxa, given in parentheses, accounts for all species and their respective infraspecific taxa (i.e., subspecies, varieties and forms when two or more are included within a single species in Singapore). For a more detailed breakdown of the statistics presented here, see Chapter 7, Table 1.

Major plant group	Native species (taxa)	Non-native species (taxa)	Cryptogenic species (taxa)
BRYOPHYTES			
Bryophyta (Mosses)	148 (153)	3	1
Marchantiophyta (Liverworts)	121	2	0
Anthocerotophyta (Hornworts)	3	1	0
PTERIDOPHYTES			
Lycopodiopsida (Lycophytes)	12	0	2
Polypodiopsida (Ferns)	162 (163)	15	7
GYMNOSPERMS			
(Conifers etc.)	8	0	0
ANGIOSPERMS			
(Flowering plants)	2190 (2207)	472 (477)	90 (92)
Total	**2644 (2667)**	**493 (498)**	**100 (102)**

major plant groups. As research for the *Flora of Singapore* progresses and more exploration is done, these numbers will certainly need to be refined, as already exemplified by the differences presented here compared to Table 1 of Chapter 1 in the first edition (Middleton, 2019a) and compared to Table 2 in Lindsay et al. (2022).

We have encouraged all authors to give detailed nomenclatural information and ensure that all names, including synonyms, have a holotype or lectotype (or, on rare occasions, a neotype), along with details of the publication of the lectotypification when relevant. For names that have no holotype and have not yet been lectotypified, we have encouraged authors to designate lectotypes, either prior to publication of the *Flora of Singapore* or in the pages of the *Flora* itself. This typification process will not only enable a more stable nomenclatural framework for the *Flora of Singapore* but also for other taxonomic works in the region. In a small number of cases, varying factors have prevented satisfactory typification of names but these are always clearly stated in the accounts.

The descriptions in the *Flora of Singapore* are based on material from Singapore as much as possible but for many species there is too little material from the country available to make a reasonable description. In these cases, the authors have been encouraged to base their description on material from the wider region, particularly from Peninsular Malaysia, ensuring

that the description remains true to the plants as found in Singapore when the species is known to be variable across its distribution.

National conservation assessments are included for all native species in Singapore using the criteria as set out in Davison (2008) for volumes 7 and 13 and Davison (2024) for volume 4 and all future volumes. The national assessments that were used in volume 4, and will be used in all future volumes, are those given by Middleton et al. (2024) except when new evidence-based assessments have been published since or when authors of accounts explicitly override earlier assessments. The criteria for assessment of species in Singapore rely more or less exclusively on an estimate or count of the number of mature individuals in Singapore, with a slight variation in methodology for bryophytes (which will be discussed in more detail in the *Flora of Singapore* volume 2). Assessments included in Middleton et al. (2024) and in future volumes of the *Flora of Singapore* are based on best available evidence but for most species the number of mature individuals in Singapore will not have been counted accurately and will have been estimated. For many of the families, the authors will also include either the global IUCN conservation assessment or a provisional global assessment based on the author's knowledge of the species and any threats it is under.

Species presumed to be Nationally Extinct in Singapore are nevertheless included in the *Flora of Singapore*. Following Davison (2008) and Davison (2024), any plant species that has not been collected or otherwise documented for Singapore in the last 30 years is presumed to be Nationally Extinct although Chong et al. (2012) have highlighted the methodological limitations. This is a dynamic list and will likely be added to over time. Species can also, of course, be removed from this list and in recent years more than 170 species documented as being Nationally Extinct by Chong et al. (2009) have been removed from the list, in a few cases because they were wrongly included but more often because they have been collected again ('rediscovered') after a long period (Neo et al., 2024). Additionally, more than 150 species have been discovered in recent years that were previously not known to occur in Singapore (Ho et al., 2022; Neo et al., 2024). These include newly naturalising or casual species but a far greater number of species which are presumed to be native in Singapore but were simply never previously collected or for which new taxonomic research has led to the reidentification of previously misnamed material. For the most part, a lack of earlier collections indicates that a species occurs only in extremely small numbers in Singapore with consequent conservation implications.

The history of taxonomic research on plants in Singapore is discussed in Chapter 3. Any piece of taxonomic research, including any Flora account, is a snapshot of what we know at the moment in time it is published. Afterwards, as noted above, new discoveries will continue to be made and research on plant groups will continue to reveal hitherto unknown relationships. We intend to keep abreast of these findings, even after the *Flora of Singapore* is published, through the pages of *Gardens' Bulletin Singapore* and through online resources.

As discussed in Chapters 4 and 5, the plant diversity and vegetation types in Singapore are very similar to those of surrounding regions, particularly southern Peninsular Malaysia. Therefore, the number of endemic species is extremely low. The verified extant endemic vascular plant species are *Hanguana triangulata* Škorničk. & P.C.Boyce (Hanguanaceae), *Homalomena nathanielii* S.Y.Wong & P.C.Boyce (Araceae), *Litsea ridleyi* Gamble (Lauraceae), *Nervilia singaporensis* Niissalo (Orchidaceae) and *Zingiber singapurense* Škorničk. (Zingiberaceae). In Middleton et al. (2019a) the endemic status of *Litsea ridleyi* was indicated as being uncertain but recent work (de Kok & Thomas, 2026) has confirmed that the material from Borneo that

had previously been identified as this species was not correctly named, leaving Singapore as the only known distribution of the species. It is the only tree species from amongst the extant endemic species but, because *Litsea* Lam. species have bird-dispersed fleshy fruits, it would not be surprising if the species is eventually found in southern Peninsular Malaysia and/or the Riau Islands of Indonesia. *Hanguana rubinea* Škorničk. & P.C.Boyce, which was reported as being a Singapore endemic in Middleton et al. (2019a), has recently been found on Batam, one of the Riau Islands (Irsyam et al., 2025). Keng (1990) suggested that *Polyosma kingiana* Schltr. (Escalloniaceae) was endemic to Singapore but this species is also found in Peninsular Malaysia. In the protologue of *Sabia erratica* Water (Sabiaceae) it was only recorded from Bukit Timah in Singapore and van de Water (1980) noted it was only known from the type collection. This would, by definition, mean that it too was endemic to Singapore. However, as also noted by van de Water (1980), there is some doubt as to whether the correct label is attached to the specimen and, consequently, whether the locality is correct, especially as the specimen was distributed from the herbarium of the Forest Research Institute Malaysia and not from Singapore. In addition, material collected in Pahang has been identified as this species. Not only is *Sabia erratica* unlikely to be endemic to Singapore, it is highly likely that it does not occur in Singapore at all.

Three endemic vascular plant species, *Dendrobium laciniosum* Ridl. (Orchidaceae), *Neonauclea kranjiensis* K.M.Wong & W.W.Seah (Rubiaceae) and *Strychnos ridleyi* King & Gamble (Loganiaceae), have each not been seen for well over 100 years and are presumed Nationally Extinct and consequently globally Extinct (note that more recent records of *Dendrobium laciniosum*, or its synonym *Flickingeria laciniosa* (Ridl.) A.D.Hawkes, in the literature are based on misidentifications). *Thunbergia dasychlamys* Bremek. (Acanthaceae), which was thought to be endemic to Singapore, is now known to have also occurred in Peninsular Malaysia but is also believed to be globally Extinct.

Since publication of the first edition of volume 1 of the *Flora of Singapore* (Middleton et al., 2019a), there has been quite a change in our knowledge of bryophyte species in Singapore. In Middleton et al. (2019a) it was noted that there was one endemic bryophyte species, *Splachnobryum temasekense* B.C.Tan et al. (Pottiaceae). We are now aware of three more species which have not been found outside of Singapore and which must be considered endemic: *Calohypnum singapurense* (Dixon) S.He & B.C.Ho (Hypnaceae), *Gaolejeunea hoi* W.Ye & Y.M.Wei (Lejeuneaceae) and *Riccardia latifrondoides* Schiffn. (Aneuraceae). Of these, *Riccardia latifrondoides* has not been collected since 1893 and is therefore considered to be globally Extinct (Middleton et al., 2024).

The preceding paragraphs demonstrate the importance of knowing exactly what is present in Singapore and that without protection it is possible for Singapore to lose some of its plant diversity. In Chapters 6 and 7, therefore, the legal framework for conservation of Singapore's plant diversity and the implementation of conservation policy in Singapore are discussed.

Although the *Flora of Singapore* by its very nature is of direct utility and interest in Singapore, we are also sure that the rigorous approach we have taken to ensure taxonomic and nomenclatural accuracy will be of benefit for monographic and Flora projects in the wider region.