1. INTRODUCTION

D.J. Middleton

The *Flora of Singapore* is a project to catalogue and describe the diversity of all families, genera and species of bryophytes, lycophytes, ferns, gymnosperms and angiosperms that are native, naturalised or casual 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.

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 advantage of ensuring that related families are treated together but also presents logistical problems due to the need to ensure that all families for a particular volume are completed before the volume can go to press. This can potentially lead to long delays between the earliest and latest submitted manuscripts for each volume. To overcome this, we plan to publish the text of each family account online when it is ready so that authors do not have to wait to get the credit they deserve and users have ready access to the resources they need to better identify, understand and conserve Singapore's plant diversity.

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 subspecies/varieties 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 at the global and national level; uses when relevant; vernacular name(s) when known; and notes to explain taxonomic or other issues.

The *Flora of Singapore* includes all native, naturalised and casual 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 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 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 naturalised or 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,

Address: Singapore Botanic Gardens, National Parks Board, Singapore.
Doi: 10.26492/fos1.2019-01; 19 October 2019 (online & press).

which we are not including, is also 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, 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', also sometimes known as 'cryptogenic weeds'. These are particularly prevalent in families such as Poaceae and Acanthaceae. 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 activity. 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 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 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 locality where the specimen was 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 records 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 Murton, Cantley and 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 for which there are no specimens 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 in the major plant groups. As research for the *Flora of Singapore* progresses and more exploration is done, these numbers will certainly need to be refined.

We have encouraged all authors to give detailed nomenclatural information and ensure that all names, including synonyms, have a holotype or lectotype, 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* 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

Table 1. Approximate numbers of species for each major plant group divided into native and naturalised/casual species and those for which the status is uncertain.

Major plant groups	Native species	Naturalised/casual species	Status uncertain
BRYOPHYTES			
Marchantiophyta (Liverworts)	118	0	0
Bryophyta (Mosses)	161	1	0
Anthocerotophyta (Hornworts)	3	0	0
PTERIDOPHYTES			
Lycopodiopsida (Clubmosses & Spikemosses)	12	1	0
Polypodiopsida (Ferns)	164	12	4
GYMNOSPERMS			
(Conifers etc.)	8	0	0
ANGIOSPERMS			
(Flowering plants)	2222	390	50
Total	**2688**	**404**	**54**

for other taxonomic works in the region. In a small number of cases, varying factors have prevented satisfactory typification of a name but these are always clearly stated in the accounts.

The descriptions in the *Flora of Singapore* are based on specimens from Singapore as much as possible but for many species there are too few collections from Singapore 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 range.

National conservation assessments are included for all native species in Singapore using the criteria set out in Davison et al. (2008). These criteria rely more or less exclusively on an estimate or count of the number of mature individuals in Singapore. Assessments in the *Flora of Singapore* will be 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 published global IUCN conservation assessment or a provisional 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 et al. (2008), any 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 about 140 species documented as being Nationally Extinct

have been removed from the list, in a few cases because they were wrongly included but more often because they have been collected again after a long period. Additionally, almost 100 species have been discovered in recent years that were previously not known to occur in Singapore. 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. For the most part, the lack of earlier collections indicates that the species occurs only in extremely small numbers in Singapore with consequent conservation implications.

The history of taxonomic research 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* is published, through the pages of *Gardens' Bulletin Singapore* and through online resources. In time, we also intend to develop individual taxon web pages with content from the *Flora* accounts and which can be updated in response to research findings. These online resources could potentially be integrated with other online biodiversity content in Singapore and the wider region.

As discussed in Chapters 4 and 5, the plant diversity and vegetation types in Singapore are very similar to that of surrounding regions, particularly southern Peninsular Malaysia. Therefore, the number of endemic species is extremely low. The verified extant endemic species are *Hanguana rubinea* Škorničk. & P.C.Boyce, *H. triangulata* Škorničk. & P.C.Boyce (Hanguanaceae), *Zingiber singapurense* Škorničk. (Zingiberaceae) and *Splachnobryum temasekensis* B.C.Tan et al. (Pottiaceae). Keng (1990) suggested that *Polyosma kingiana* Schltr. (Escalloniaceae) was endemic to Singapore but this species is also found in Peninsular Malaysia. *Sabia erratica* Water (Sabiaceae) is 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.

Three endemic species, *Dendrobium laciniosum* Ridl. (Orchidaceae), *Strychnos ridleyi* King & Gamble (Loganiaceae) and *Neonauclea kranjiensis* K.M.Wong & W.W.Seah (Rubiaceae) 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* Ridl., or its synonym *Flickingeria laciniosa* (Ridl). A.D.Hawkes, in the literature are based on misidentifications – Kurzweil, pers. comm.). A fourth species, *Thunbergia dasychlamys* Bremek., which was thought to be endemic to Singapore, is now known to have once also occurred in Peninsular Malaysia (De Kok, pers. comm.) but is also believed to be globally Extinct.

Without protection Singapore would lose more 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 anticipate 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.