A summary of the total vascular plant flora of Singapore

K.Y. Chong[1], Hugh T.W. Tan and Richard T. Corlett

Department of Biological Sciences,
National University of Singapore,
14 Science Drive 4, Singapore 117543
[1]kwek@nus.edu.sg

ABSTRACT. The last analysis of the vascular plant flora of Singapore was published more than a decade ago. Since then, the conservation statuses of all native species have been assessed and more exotic species have been recognised as naturalised. We present a holistic view of the family compositions and life forms of the total flora, including many exotic species that are found in cultivation only and not yet escaped or naturalised. Excluding extinct species, exotic species now outnumber native species. Horticultural introductions have also strongly influenced family compositions: legumes and palms are now the most species-rich families in the total flora. Legumes are also a dominant family among all naturalised life forms. We briefly discuss these implications for local conservation ecology.

Keywords. Cultivation, exotics, extinctions, natives, naturalisations, total flora, vascular plants

Introduction

Singapore's vascular plant flora is relatively well-documented for a tropical country. The first compilation was the *Flora of Singapore* by Ridley (1900) and his supplementary notes that shortly followed (Ridley 1901). The checklist by Turner et al. (1990) was the first, comprehensive, published update to Ridley (1900), and incorporated an unpublished Flora of Syonan compiled by the staff of the Singapore Botanic Gardens' Herbarium during the Japanese Occupation from 1942 to 1945, as well as Corlett's (1988) list of naturalised plant species. Turner et al.'s checklist was subsequently expanded into a fully-referenced list of vascular plant names (Turner 1993). Keng's (1973–1987) annotated lists of seed plants of Singapore were developed into the two volumes of the *Concise Flora of Singapore* (Keng 1990, Keng et al. 1998). These publications formed the backbone of subsequent updates and additions, and included native species, naturalised exotics, known escapes from cultivation and the most commonly cultivated species.

Two rounds of conservation assessments were conducted for the vascular plants and published as the first and second editions of the *Singapore Red Data Book* respectively (Ng & Wee 1994, Davison et al. 2008). With the second round of assessments, every native vascular plant species, with the exception of those few overlooked by past publications, has been assigned a conservation status. In addition, two editions of the *1001 Garden Plants in Singapore* (Boo et al. 2006) listed many more vascular plant species that are cultivated in Singapore. Although not a strictly botanical work, this book advanced our knowledge of the large numbers of plants

that have been introduced into Singapore via horticulture. The chronology of these publications is summarised in a timeline in Fig. 1.

Although past work has already described the taxonomic composition and life-forms of the Singapore vascular plant flora, these have focused on various components such as the naturalised exotics (Corlett 1988) or the native species (Turner 1994, Turner et al. 1994). None of the studies, however, have taken a holistic approach to the floristic composition from a total flora perspective, i.e., one that takes into account all species found in the country, including exotics found in cultivation only.

We recently compiled a checklist of the total vascular plant flora of Singapore (Chong et al. 2009). In this paper, we summarise our findings on the taxonomic composition and life forms from a total flora perspective.

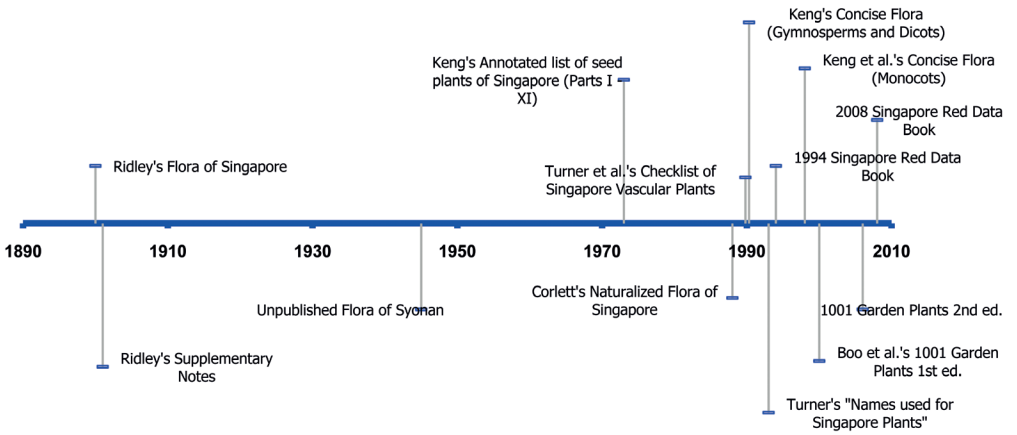

Fig. 1. Timeline of the major publications used in the compilation of a total flora of Singapore.

Materials and methods

Key reference sources and the methodology employed in the compilation of the flora used in this analysis is given in Chong et al. (2009). In summary, all plant names given in the local floristic literature reviewed above were compiled into a spreadsheet and checked for synonyms. Species that were inferred to have been present in Singapore before human-mediated introductions are considered "native". Native species that have not been collected or seen by botanists in the last 30 years are considered "extinct", as defined in Davison et al. (2008). Species whose presence is a result of human involvement are considered "exotic". Exotic species that have established outside of cultivation but rely on repeated introductions of propagules for persistence in the wild are termed "casual". Exotic species that maintain self-replacing populations in the wild independent of new human introductions are termed "naturalised". Remaining exotic species that can only be found in cultivation are termed "cultivated-only". For those weedy species that can only be found in human-modified habitats in Singapore,

for which we lack knowledge of their original biogeographic range, we apply the term "cryptogenic" following the terminology by Carlton (1996).

Since the publication of our checklist, we have been continually updating and correcting our database upon encountering new literature and information provided by users of the checklist. Family circumscriptions of seed plants follow that of the Angiosperm Phylogeny Group (APGIII 2009, Stevens 2001 onwards), while non-seed plants follow Smith et al. (2006). The results presented here represent the most updated version of this database.

Results and discussion

In our checklist, we reported relative proportions of native, exotic and cryptogenic species. Here we report almost identical figures: there are 2141 native, 1822 exotic, and 210 cryptogenic species, constituting 51%, 44% and 5% of the total flora, respectively. The number of exotic species is an underestimate, as we are likely to have left out many other less commonly cultivated species in private gardens and nurseries.

Extinctions and introductions have had a major impact on the representation of families in the total flora (Table 1). The Orchidaceae was the largest native family, but massive extinctions, small numbers of species in cultivation and the absence of spontaneous exotics has reduced its rank to eighteenth in the total extant flora. The Rubiaceae, as the second largest native family, sustained far fewer extinctions and remains dominant as the largest extant native family and the third largest in the total extant flora. The Fabaceae is now the largest family overall as a result of high numbers of both spontaneous and cultivated exotics, followed by the Arecaceae, which has the largest number of cultivated species.

Trees are the most common life form for both natives and exotics (Fig. 2). Among the extant woody natives, the Rubiaceae are the largest family, with 17 extant tree species and 41 extant shrub species. These dominate the forest understorey. Among the native trees, the Meliaceae has sustained the largest number of extinctions (14 species; 35%), larger in proportion than other major families of trees. This may be attributed to the declines and extinctions of large frugivores that disperse the large-fruited Meliaceae, resulting in lack of recruitment and consequently decreased chances of population persistence (Corlett 2007).

Epiphytes are the only life form where most of the species have become extinct (Fig. 2a). Turner et al. (1994) noted that most of the epiphyte extinctions are accounted for by the epiphytic habit of the orchids, and that ferns, the second largest group of epiphytes, sustained proportionally far less extinctions. Here we repeat this observation but also show that the Apocynaceae and the Loranthaceae, the third and fourth largest families of epiphytes respectively, have suffered more than 50% extinctions (Table 2). The Apocynaceae epiphytes consist of only two genera: *Hoya* and *Dischidia*. The Loranthaceae consist solely of hemi-parasitic mistletoes. The susceptibility of epiphytes to extinction therefore appears to be consistent at least among flowering plant families.

Table 1. Largest 20 families in the vascular plant flora of Singapore. Ranks of 10 largest families within each category are given in superscript to the right of the number of species.

Family	All Natives	Extinct	Extant	Cryptogenic	All Exotics	Naturalised	Casual	Cultivated-only	All Wild	All Present
Fabaceae	61 [5]	11 [10]	50 [3]	8 [5]	190 [1]	46 [1]	10 [2]	134 [2]	104 [1]	248 [1]
Orchidaceae	226 [1]	181 [1]	45 [6]	1	7	0	1	6	46 [9]	53
Arecaceae	54 [9]	16 [5]	38	0	173 [2]	3	2	168 [1]	41	211 [2]
Rubiaceae	124 [2]	39 [2]	85 [1]	10 [4]	43 [9]	9 [5]	0	34 [10]	104 [1]	138 [3]
Poaceae	49	6	43 [7]	32 [2]	57 [5]	23 [2]	12 [1]	22	98 [3]	132 [4]
Myrtaceae	55 [8]	14 [7]	41 [9]	0	73 [3]	1	3 [8]	69 [3]	42	114 [5]
Apocynaceae	67 [3]	25 [3]	42 [8]	0	50 [7]	3	2	45 [6]	45 [10]	92 [6]
Cyperaceae	51 [10]	10	41 [9]	44 [1]	7	2	0	5	87 [4]	92 [6]
Malvaceae	37	6	31	7 [7]	54 [6]	3	4 [6]	47 [5]	41	92 [6]
Moraceae	60 [7]	10	50 [3]	1	31	1	7 [3]	23	52 [6]	82 [10]
Euphorbiaceae	48	12 [8]	36	4	39	10 [4]	3 [8]	26	50 [8]	79
Acanthaceae	16	5	11	6 [10]	66 [4]	6 [6]	4 [6]	56 [4]	23	83 [9]
Phyllanthaceae	61 [5]	12 [8]	49 [5]	0	16	3	1	12	52 [6]	65
Annonaceae	67 [3]	8	59 [2]	0	9	0	1	8	59 [5]	68
Araceae	30	2	28	4	41 [10]	5 [8]	6 [4]	30	37	73
Lamiaceae	23	9	14	7 [7]	39	5 [8]	5 [5]	29	26	60
Dipterocarpaceae	33	3	30	0	35	0	0	35 [8]	30	65
Asteraceae	6	1	5	14 [3]	45 [8]	16 [3]	3 [8]	26	35	64
Meliaceae	41	15 [6]	26	0	19	0	2	17	26	45
Melastomataceae	50	17 [4]	33	0	10	1	0	9	34	43

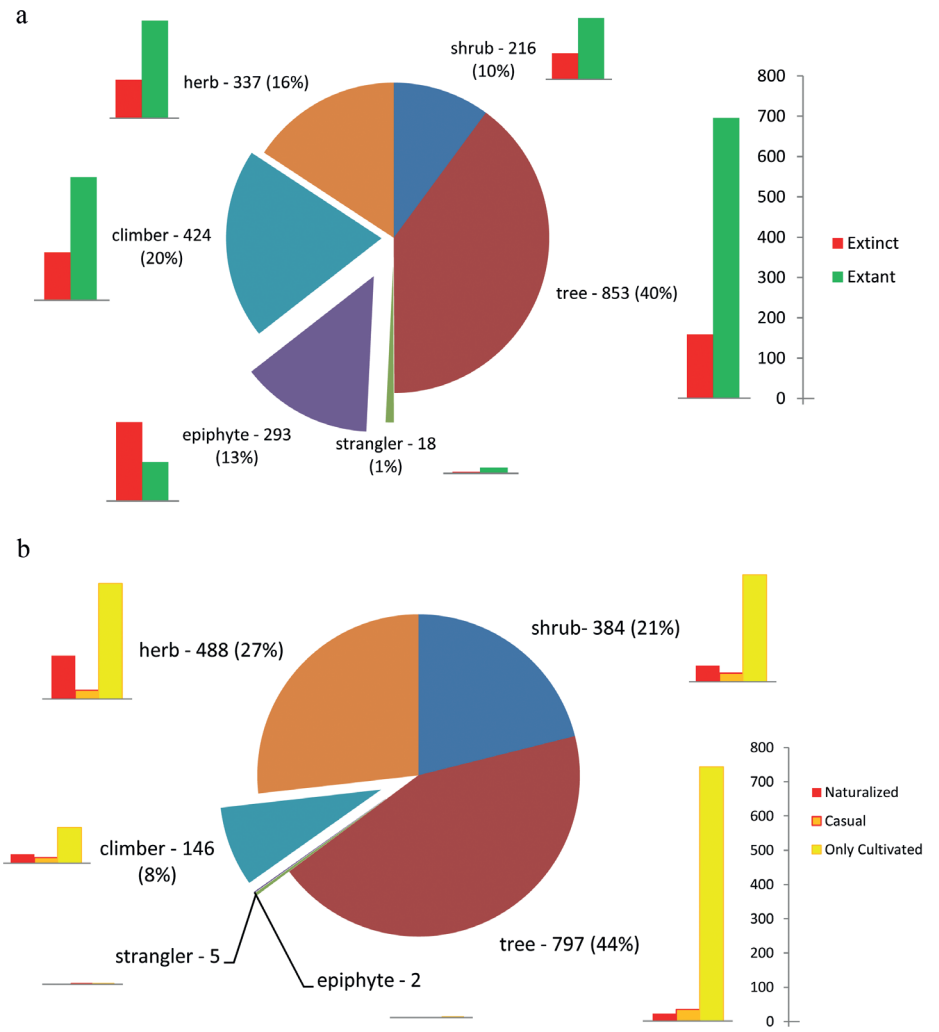

Fig. 2. Life forms of the (a) native and (b) exotic vascular plant species of Singapore.

Table 2. Largest five families of epiphytes in Singapore.

	No. of Epiphytic Species		
Family	All	Extinct	Extant
Orchidaceae	164	142	22
Polypodiaceae	19	3	16
Apocynaceae	17	9	8
Loranthaceae	14	8	6
Hymenophyllaceae	13	4	9

Of the exotic growth habits, the herbs have the largest proportion of naturalised species although more tree species were introduced for cultivation (Fig. 2b). Among the naturalised exotic species, the five largest families of climbers are Fabaceae (7 species), Convolvulaceae (4 species), Passifloraceae (3 species), Acanthaceae (2 species) and Cucurbitaceae (2 species). The five largest families for naturalised, non-climbing woody species are Fabaceae (29 species), Euphorbiaceae (5 species), Verbenaceae (5 species), Urticaceae (4 species) and Solanaceae (3 species). Finally, the 10 largest families of naturalised, non-climbing herbs are the Poaceae (23 species), Asteraceae (15 species), Fabaceae (10 species), Rubiaceae (8 species), Euphorbiaceae (5 species), Acanthaceae (4 species), Araceae (4 species), Amaranthaceae (4 species) and Cleomaceae (4 species). Many of these naturalised herbs are garden weeds or open wasteland ruderals and do not pose a threat to native forests. The woody naturalised species may be more of a cause for concern: some of the legumes form exotic-dominated woodlands where recruitment and regeneration of native species are slow, while other species such as *Cecropia pachystachya* Trécul (Urticaceae), *Ptychosperma macarthurii* (H.Wendl. ex H.J.Veitch.) H.Wendl. ex Hook.f. (Arecaceae) and *Syngonium podophyllum* Schott (Araceae) have been found in native forests edges and gaps (Lok et al. 2010).

Our compilation of a total vascular flora is the first for the tropics, and includes both the remnants of the original tropical rainforest cover as well as the elements of introduced flora from urbanisation. After taking extinctions into account, exotic species richness now exceeds native species richness. Considering that many of the native species are endangered and have small population sizes, while some exotic species have been planted in high densities throughout Singapore, the relative abundance of exotics to natives is also likely to reflect this. Although a large number of exotic species have been introduced, only a fraction has become naturalised, but more studies are needed to evaluate the impacts of these naturalisations on the local flora and fauna. Non-naturalised exotics in the urban environment also interact with native and exotic animals, providing nesting sites and food. Given the influence that cultivation can have on the floristic composition, replacing exotic horticultural species with native plants may be a strategy for conservation. Functional diversity lost from extinctions can be regained by reintroductions of extinct species, and populations of rare species can be augmented with horticultural plantings, while reducing the risks of invasive species introductions.

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