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Rediscoveries, new records, and the floristic value of the Nee Soon freshwater swamp forest, Singapore

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ABSTRACT. The unique plant communities of the freshwater swamp forests of southern Johor (Malaysia) and Singapore attracted the attention of E.J.H. Corner, but there have been no comprehensive follow-up studies to his seminal work. Meanwhile, freshwater swamp forests in the region have been mostly lost to logging and in-filling for plantations or urban development. The Nee Soon catchment contains the last substantial tract of this forest type in Singapore. We collated the rediscoveries of vascular plant species presumed Nationally Extinct in the 2nd and latest edition of the *Singapore Red Data Book*, and new records for the Singapore vascular plant flora from the Nee Soon catchment, including those that we found and collected through the establishment and survey of 40 vegetation plots, each 20 × 20 m. We have identified 672 species from 117 families, of which 288 are trees from 60 families represented by at least one stem ≥ 5 cm DBH. The catchment is especially species rich and abundant in the Myristicaceae. In the last ten years, 53 rediscoveries, 11 new species records, and two new varietal records have been uncovered from (or can be found in) the Nee Soon catchment. The Nee Soon freshwater swamp forest is one of Singapore's most valuable botanical areas, and warrants sustained conservation effort and study.

Keywords. Floristic value, freshwater swamp forest, new records, rediscoveries

"…pockets of vegetation remain and from these botanists may pick up and extend where I, perforce, have withdrawn."

E.J.H. Corner (1978: 1)

Introduction

In a supplement of this journal in 1978, the eminent botanist Edred John Henry Corner described his observations on the unique freshwater swamp forests in the far south of Peninsular Malaysia and Singapore. Most of his observations and collections were made from opportunities provided by the felling of such forest in the 1930s. This

deforestation continued unabated in the decades that followed, almost to completion. A wealth of research has been written and published about the Amazonian wetland forests (e.g. Junk et al., 2010), but in comparison, few studies have been made since Corner's seminal work to update our knowledge of tropical freshwater swamp forests in this part of the world (Turner et al., 1996a) where they are no less special. The recent literature on freshwater swamp forests in insular Southeast Asia is focused predominantly on peat swamp forests (swamp forests with a deep layer of ombrogenous peat) because of interests in preserving the massive below ground carbon stocks and avoiding transboundary air pollution arising from the burning of this particular swamp forest type (Yule, 2010; Posa et al., 2011). There is no historical evidence of true peat swamp forests in Singapore (see also Nguyen et al., 2018), therefore in this article we exclude peat swamps in our use of the term 'freshwater swamp forest'.

Freshwater swamp forest was suggested by Corlett (1991) to have once constituted 5% of the vegetation of Singapore prior to modern human settlement. The swamp forests at Mandai Road and Jurong were among the main study sites of Corner (1978). Most of the Mandai swamp was flooded to become part of the Upper Seletar Reservoir, while the Jurong swamp was in-filled to be used as industrial land. Today, the freshwater swamp forest at Nee Soon is the country's last substantial remnant of this forest type (Turner et al., 1996a). This paper presents a portion of our research focusing on the vegetation and plant communities in the Nee Soon catchment, conducted as part of a larger project (Davison et al., 2018) to understand the biodiversity and hydrology of the Nee Soon freshwater swamp forest that is within this catchment.

Prior to our study, 16 vascular plant species that were presumed Nationally Extinct in Singapore in the most recent edition of the *Singapore Red Data Book* (ferns and fern allies: B.C. Tan et al., 2008; seed plants: H.T.W. Tan et al., 2008) were rediscovered in the Nee Soon catchment and published in various sources (Table 1). One new species record, *Hoya caudata* Hook.f. (Apocynaceae), was reported by Rodda & Ang (2012). Therefore, the Nee Soon catchment was already a known prime spot for new records and rediscoveries leading Chong et al. (2012) and the authors of many of the references listed in Table 1 to call for more botanical exploration of the patch of freshwater swamp forest in this catchment.

Turner et al. (1996a) compiled a list of freshwater swamp vascular plant species in Singapore from three of the clusters of plots studied by Wong et al. (1994) for trees, and Turner et al. (1996b) for herbs, that were in the freshwater swamp forest areas of Nee Soon, and supplemented this with the species recorded by Corner (1978) at Mandai and Jurong, as well as with past herbarium specimens. Wong et al. (2013) produced a preliminary checklist of all the land plant species (i.e., including mosses and liverworts) of the Nee Soon catchment by adding data from newly surveyed plots, including ten 15 × 15 m plots established in the earlier Phase 1 of this project, and recently collected herbarium specimens. During Phase 2 of this project, we were able to re-assess the vascular plant species in Wong et al. (2013) and correct some of the nomenclature and identifications (for details, see Chong et al., 2016; Lim et al., 2016; Neo et al., 2016; Tan et al., 2016). The physical, climatic and ecological context of the Nee Soon freshwater swamp forest is described by Clews et al. (2018).

Table 1. Sixteen species presumed Nationally Extinct but rediscovered in the Nee Soon swamp forest after the publication of the 2nd edition of the *Singapore Red Data Book*, and documented by various sources, prior to our study.

S/No.	Species	Family	Habit	Reference
1.	*Aeschynanthus albidus* (Blume) Steud.	Gesneriaceae	Epiphyte	Lok & Tan (2008)
2.	*Bulbophyllum singaporeanum* Schltr.	Orchidaceae	Epiphyte	Yam et al. (2010)
3.	*Callostylis pulchella* (Lindl.) S.C.Chen & Z.H.Tsi	Orchidaceae	Epiphyte	Lok et al. (2012)
4.	*Coelogyne rochussenii* De Vriese	Orchidaceae	Epiphyte	Lok et al. (2011b)
5.	*Dendrobium aloifolium* (Blume) Rchb.f.	Orchidaceae	Epiphyte	Ang et al. (2010b)
6.	*Dischidia hirsuta* (Blume) Decne.	Apocynaceae	Epiphyte	Rodda et al. (2012)
7.	*Ficus delosyce* Corner	Moraceae	Strangler	Ang et al. (2014)
8.	*Freycinetia javanica* Blume	Pandanaceae	Climber	Ang et al. (2012a)
9.	*Hetaeria obliqua* Blume	Orchidaceae	Herb	Leong & Yam (2013)
10.	*Liparis barbata* Lindl.	Orchidaceae	Herb	Lok et al. (2010)
11.	*Pinanga simplicifrons* (Miq.) Becc.	Arecaceae	Clumping palm	Ang et al. (2010a)
12.	*Polystachya concreta* (Jacq.) Garay & H.R.Sweet	Orchidaceae	Epiphyte	Lok et al. (2011a)
13.	*Pterisanthes cissioides* Blume	Vitaceae	Climber	Yeo et al. (2012)
14.	*Renanthera elongata* (Blume) Lindl.	Orchidaceae	Herb	Ang et al. (2011)
15.	*Salacca affinis* Griff.	Arecaceae	Clumping palm	Loo (2011)
16.	*Trichotosia velutina* (Lodd. ex Lindl.) Kraenzl.	Orchidaceae	Epiphyte	Ang et al. (2012b)

Methods

Our 20 × 20 m vegetation plots were briefly described by Chong et al. (2016). Nine of the ten plots from the earlier phase of the project were extended and re-surveyed; one plot was discarded because it fell outside of the new delineation of the Nee Soon catchment. Using a preliminary digital elevation model developed during the earlier project phase, we divided the study area into five elevational strata: 0–20, 20–40,

40–60, 60–80, and 80–100 m. Within each stratum, we generated 20 random points as candidate locations for our plots. Our aim was to locate half of our plots of each stratum in 'wet' areas (defined by the presence of surface water such as swamp pools or streams), and half in 'dry' areas (without such surface water), taking also into account the nine plots from the earlier project phase. We then visited each randomly generated location in turn and established a plot if the conditions of the location satisfied our targeted plot type. Our 'wet' plot conditions were more difficult to sample by random chance in the study area, therefore in a few cases where the randomly generated location was near to but not directly over surface water, we shifted the plot location. The index numbers of the plots that were shifted are suffixed by an 'a' (Table 2).

In each plot, all vascular plant species present were recorded. Where field identification was not possible, a voucher specimen was collected to be used for further investigation. All woody stems ≥ 5 cm diameter at a height of 1.3 m from the ground (i.e. diameter at breast height or DBH) were also measured; again, where field identification was not possible, an attempt was made to collect leafy twigs as voucher specimens. When branches were too high to be collected even with extendable pruners (with about 6 m reach), we observed the leaves through a pair of high-powered (10 × 50) binoculars, or photographed them with a telescopic lens, and then searched for fallen leaves that matched these on the ground. Sometimes, if shorter, younger individuals deemed to be of the same species were present nearby and had accessible branches, we collected these instead. When the tree crown was too high for the leaves to be viewed clearly even through binoculars or a telescopic lens, or where infestation by climbers obscured the visibility of the leaves, scrapings of the inner bark and sapwood were taken and passed to another project team to extract DNA barcodes (see Kutty et al., 2018) as a last resort to provide a putative identification to family or genus. The outer bark, inner bark and sapwood characteristics, together with observations of latex, resin, or odour, were then used to further narrow down the identity to probable species if possible, or were used to complement the identification with leafy twigs or fallen leaves.

The fresh voucher specimens were pressed and dried in an oven at 60°C for a few days. To identify the specimens, we consulted published taxonomic keys and descriptions, and matched them with other specimens deposited in the Singapore Botanic Gardens' Herbarium (SING) which had been determined by visiting experts. Arising from our investigations with fresh and herbarium specimens, we have started a series of field guides to various families of trees in the Nee Soon catchment: Lauraceae (Chong et al., 2016), *Cratoxylum* Blume (Hypericaceae; Neo et al., 2016), Myristicaceae (Lim et al., 2016), and *Xanthophyllum* Roxb. (Polygalaceae; Tan et al., 2016). In this paper, we will focus on reporting the rediscoveries, new records, and summary statistics of the flora by family and conservation status. A complete set of vouchers, i.e., containing at least one specimen of every species identified from our plots, was deposited with the Herbarium, Lee Kong Chian Natural History Museum, National University of Singapore (SINU). Collection numbers for the first and second phases of the project begin with 'NSSF1' and 'NSSF2' respectively. If the collections were made from within our plots, this was followed by the plot location; if the specimen

Table 2. The categorisation of plots according to preliminary elevational strata and hydrological conditions.

Elevation (m)	Wet plots	Dry plots
Phase 1	Q3, Q4, Q6, Q9, Q10	Q1, Q2, Q7, Q8
Phase 2		
0–20	Q104, Q105, Q111, Q112	Q101, Q102, Q107, Q109
20–40	Q203a, Q206, Q209, Q220	Q204, Q208, Q213, Q217
40–60	Q301, Q308a, Q311a, Q319a, Q320a	Q302, Q305, Q306, Q307
60–80	Q404a, Q414a	Q405, Q408
80–100	Q504	Q509
Total number	**21**	**19**

was collected from a measured woody stem, the collection number contained a 'T' followed by the serial number of the stem (e.g., see Appendix 1). A map of the final plot locations (Fig. 1) was printed on the back of the specimen labels of our voucher specimens for ease of reference.

Rediscoveries

Of the species that were listed as presumed Nationally Extinct in the 2nd edition of the *Singapore Red Data Book* (B.C. Tan et al., 2008; H.T.W. Tan et al., 2008), 61 were later "rediscovered", based on herbarium specimens collected after its publication. These 61 rediscoveries were compiled by Chong et al. (2012). We recorded 21 of these 61 species in our plots (Table 3). We also recorded: *Ampelocissus cinnamomea* (Wall. ex M.A.Lawson) Planch., which was recently rediscovered in the Bukit Timah Nature Reserve (Ng et al., 2014), and *Globba pendula* Roxb. (Zingiberaceae), which was also recently reported as rediscovered by Niissalo et al. (2017). Their presence in Nee Soon adds a new locality for these two species as the earlier records were all from other parts of Singapore. Another species, *Plocoglottis lowii* Rchb.f. (Orchidaceae), was first rediscovered and reported from Upper Seletar Reservoir at a locality just outside of the Nee Soon catchment (Niissalo et al., 2016), but the lead author later found another population near one of our plots: Q306 (M.A. Niissalo, personal communication). *Aeschynanthus pulcher* (Blume) G.Don (=*Aeschynanthus parvifolius* R.Br.) was also reported as rediscovered from the Nee Soon swamp forest by Williams (2014). We did not encounter *Plocoglottis lowii* and *Aeschynanthus pulcher* ourselves during our study.

We provide brief accounts below of the rediscovery of twelve more presumed Nationally Extinct species from our plots, including recent unreported collections by others. Collection details are in Appendix 1.

Table 3. Twenty-one of the 61 rediscoveries compiled by Chong et al. (2012) were collected in our plots. The table shows their presence in the Nee Soon catchment in this study. Occurrence refers to the number of plots where the species was present, while the number of stems refers to the number of woody stems ≥ 5 cm DBH.

S/No.	Species	Family	Habit	Occurrence	No. of stems
1.	*Actinodaphne macrophylla* (Blume) Nees	Lauraceae	tree	4	1
2.	*Aglaia elliptica* Blume ssp. *elliptica*	Meliaceae	tree	2	1
3.	*Dalbergia parviflora* Roxb.	Fabaceae	climber	1	
4.	*Dichapetalum sordidum* (Hook.f.) Leenh.	Dichapetalaceae	climber	1	
5.	*Dioscorea orbiculata* Hook.f. var. *tenuifolia* (Ridl.) Thapyai	Dioscoreaceae	climber	9	
6.	*Dracaena singapurensis* Ridl.	Asparagaceae	shrub	1	
7.	*Fagraea splendens* Blume	Gentianaceae	epiphyte	4	
8.	*Friesodielsia glauca* (Hook.f. & Thomson) Steen.	Annonaceae	climber	9	
9.	*Grenacheria amentacea* (C.B.Clarke) Mez	Primulaceae	climber	9	
10.	*Helicia excelsa* (Roxb.) Blume	Proteaceae	tree	2	
11.	*Hypserpa nitida* Miers	Menispermaceae	climber	2	
12.	*Knema glaucescens* Jack	Myristicaceae	tree	3	2
13.	*Meliosma pinnata* (Roxb.) Maxim. ssp. *ridleyi* (King) Beusekom	Sabiaceae	tree	1	
14.	*Neesia malayana* Bakh.	Malvaceae	tree	4	5
15.	*Nephelium laurinum* Blume	Sapindaceae	tree	6	5
16.	*Rourea acutipetala* Miq. ssp. *acutipetala*	Connaraceae	climber	6	
17.	*Salacia maingayi* M.A.Lawson	Celastraceae	climber	2	
18.	*Strychnos axillaris* Colebr.	Loganiaceae	climber	1	
19.	*Syzygium kunstleri* (King) Bahadur & R.C. Gaur	Myrtaceae	tree	1	1
20.	*Syzygium scortechinii* (King) Chantar. & J.Parn.	Myrtaceae	tree	1	
21.	*Uncaria attenuata* Korth.	Rubiaceae	climber	1	

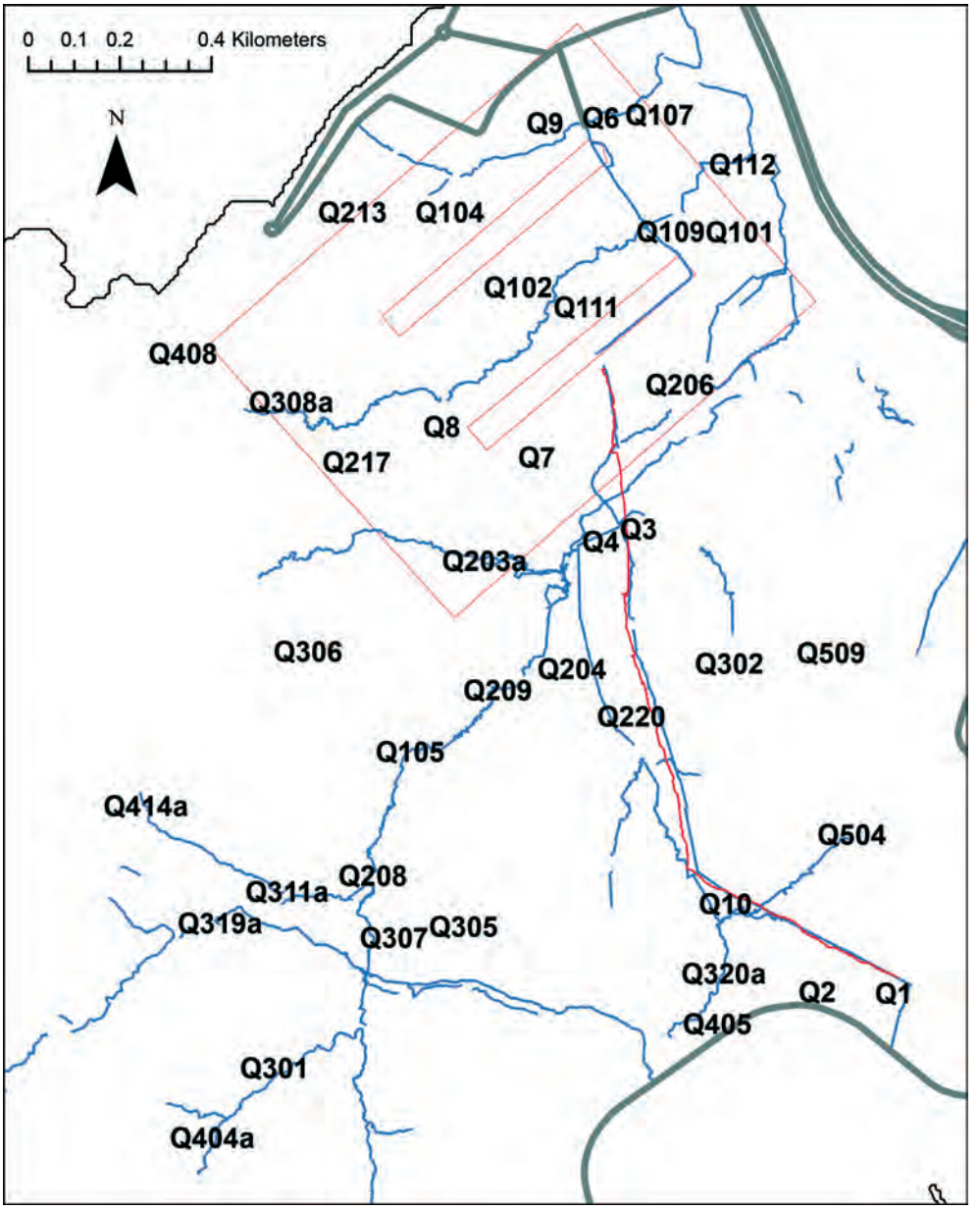

Fig. 1. Map of plot locations printed on the back of the labels of our deposited voucher specimens.

1. *Aglaia tenuicaulis* Hiern (Meliaceae)
Listed as present in Singapore in several treatments (e.g. Pannell, 1989; Pannell, 2013) without any specimens cited. Ridley (1900) had indicated that it was "perhaps an error". The only specimen of this species we know of that is collected from Singapore is deposited in the herbarium of the Royal Botanic Gardens at Kew (*Lobb s.n.*; cited in Pannell, 1992). The two collections made in our study were identified as *Aglaia tenuicaulis* based on the reddish-brown stellate hairs interspersed with pale-brown stellate hairs and scales present on the lamina below. The twig apices are also densely covered in reddish-brown stellate hairs. This species has large compound leaves up to 1.3 m long, with 3−5 large leaflets each up to 45 cm long and 14 cm wide, and 16−19 pairs of lateral veins. According to Pannell (1989), this is a small tree common in the Malay Peninsula, in lowland or hill dipterocarp forest.

2. *Baccaurea macrophylla* (Müll.Arg.) Müll.Arg. (Phyllanthaceae)
This species was most recently collected from MacRitchie Reservoir (*Corner s.n.*, 29 Oct 1944 [SING0012586]). It was also previously collected from Bukit Mandai (*Mohd Noor s.n.*, 28 Nov 1917 [SING0012585]). As suggested by its name, *Baccaurea macrophylla* is a large-leaved member of the genus. It can be recognised by a distinct set of characteristics: prominent stipules up to 11 × 11.5 mm in size, stellate hairs, discoid glands present in a row between secondary veins on its lower leaf surface, and a papery leaf texture. It is a medium-sized tree and can be found in primary and secondary rainforests, as well as peat swamp forests (Haegans, 2000).

3. *Callistopteris superba* (Backh. ex T.Moore) Ebihara & K.Iwats. (Hymenophyllaceae)
Previously collected only once from Bukit Timah (*Ridley s.n.*, 1897 [SING0031767]) and another time from Seletar Woods (*Matthew s.n.* [SING0032459]). Terrestrial fern with erect rhizomes and stout roots, winged stipes, and glandular hairs on the underside of the lamina. In the *Singapore Red Data Book*, this was listed under the name *Cephalomanes superbum* (Backh. ex T.Moore) I.M.Turner; another synonym used locally is *Trichomanes superbum* Backh. ex T.Moore (Turner, 1995; Ebihara et al., 2006).

4. *Deplanchea bancana* (Scheff.) Steenis (Bignoniaceae)
A recent collection of this species was made near the Nee Soon pipeline (*Leong et al. SING2013-100*, 20 May 2013). Prior to this, it was collected from Kranji (*Goodenough s.n.*, 18 Dec 1889 [SING0166223]), from one tree in Bukit Timah (Corner, 1988: 176; *Corner s.n.*, 8 Jul 1938 [SING0004012, SING0004015]), and listed by Corner (1978) as found in the now-lost freshwater swamp forest at Mandai. It is easily recognised by its simple, fairly large, whorled leaves covered with light-coloured hairs, with glands at the cordate base of the lamina. According to Kochummen (1978a: 37), this is a tall tree with a fluted base and steep buttresses which occurs especially by swampy streams.

5. *Dioscorea stenomeriflora* Prain & Burkill (Dioscoreaceae)
According to Turner et al. (1994), one specimen was collected from the Central Catchment Nature Reserve near the west end of Upper Peirce Reservoir with the collection number *NRS1632*, but we are unable to trace this specimen. Otherwise, there is one collection from Changi (*Ridley s.n.*, Feb 1894 [SING0010181]). It is a left-twining climber, with oblong laminas up to 16 cm long, with sagittate bases in younger leaves. Secondary veins are distinct and widely spaced.

6. *Lindsaea repens* (Bory) Thwaites var. *pectinata* (Blume) Mett. ex Kuhn (Lindsaeaceae)
This was only collected once previously from Bukit Timah (*Ridley s.n.*, 1893 [SING0031423]). A low-climbing or epiphytic fern with long-creeping rhizomes, quadrangular rachis, and asymmetrical lamina.

7. *Syzygium glabratum* (DC.) Veldkamp (Myrtaceae)
The most recent collection of this species was from the Raffles College grounds (*Md. Nur SFN 36293*, 13 Jun 1939), but previous collections were all from MacRitchie Reservoir (*Corner SFN 36291*, 5 Jun 1939), or the Reservoir Jungle (*Corner s.n.*, 8 May 1936, [SING 0011827], *Corner SFN 29225*, 31 Mar 1935; *Corner s.n.*, 20 Apr 1933 [SING 0011825, SING 0011835]). It had previously been collected and listed for Singapore under various names: *Eugenia fusiformis* Duthie, *Eugenia virens* (Blume) Koord. & Valeton and *Syzygium gracile* (Korth.) Amshoff (see Turner, 1995; Veldkamp, 2003). *Syzygium glabratum* can be identified by well-spaced main lateral veins raised on both sides of the lamina, and extremely dense, minute, dark glandular pits or dots over the entire lower lamina surface, which are nested within the cells of the fine tertiary reticulations, visible even to the naked eye. It is an uncommon tree found from Singapore to Peninsular Malaysia, Borneo, Java, and the Philippines (Kochummen, 1978b; Ashton, 2011).

8. *Syzygium leptostemon* (Korth.) Merr. & L.M.Perry (Myrtaceae)
This species was most recently collected from Bukit Timah (*Ngadiman 34994*, 15 Jun 1938; *Ridley 11324*, 1903), and also from Ang Mo Kio (*Ridley 25*, Mar 1889). *Syzygium leptostemon* has large elliptic-obovate laminas with well-spaced main lateral veins that are raised on the underside of the lamina. The twigs are often angular, distinctly orange-brown (sometimes grey-brown), contrasting in colour with the leaves, which dry very dark. It is known to be locally common where it occurs, but favours wet environments such as floodplains, river banks, and swamp forest (Kochummen, 1978b; Ashton, 2011).

9. *Syzygium pseudocrenulatum* (M.R.Hend.) I.M.Turner (Myrtaceae)
This species was most recently collected in Singapore from Mandai (Corner, 1978; *Corner 28090*, 25 Apr 1924) and also from an unspecified locality (*Ridley 6232*, 1894). *Syzygium pseudocrenulatum* is distinct in its thickly leathery, elliptic to oblong-elliptic

lamina with conspicuous glandular pits or dots visible on both sides and slightly crenate margins. It is endemic to Peninsular Malaysia and Singapore (Kochummen, 1978b).

10. *Trigoniastrum hypoleucum* Miq. (Trigoniaceae)
This species was most recently collected from Bukit Timah Nature Reserve (*Khoo KMS 105*, 17 Jul 2009), as were previous collections (*Ngadiman SFN 36148*, 21 May 1940; *Ngadiman 34965*, 5 May 1938; *Ridley 10379*, 1899). The sole member of its genus, this species is recognised by its simple, alternate leaves, which have whitish lower lamina surfaces owing to a spiderweb-like covering of appressed hairs, and distinct, finely-reticulate venation. Also diagnostic are the minute impressed glands that line and thicken the lamina margins and apex. *Trigoniastrum hypoleucum* is also found in lowland rainforests in Peninsular Malaysia, Borneo, and Sumatra (Van Steenis, 1949: 58–60).

11. *Uvaria curtisii* King (Annonaceae)
This species was most recently collected from multiple localities: Upper Peirce Reservoir (*Gwee SING 2009-461*, 17 Nov 2009; *SING 2010-127*, 19 Jan 2010), MacRitchie Reservoir (*Gwee SING 2009-602*, 15 Dec 2009), and Bukit Timah (*Gwee SING 2010-097*, 5 Jan 2010). Prior to this, it was collected in Bukit Timah (*Sinclair SF 39652*, 27 May 1953). The oblong or oblanceolate laminas of this large woody climber are covered with soft, rusty-brown, stellate hairs usually 0.5 mm (and not more than 1 mm) long. *Uvaria curtisii* is otherwise known only from Peninsular Malaysia (Sinclair, 1955: 206–207.)

12. *Uvaria lobbiana* Hook.f. & Thomson (Annonaceae)
A recent collection of this species was made from the Nee Soon forest (*Lua SING 2011-237*, 22 Jun 2011). Prior to this, it was last collected from the Singapore Botanic Gardens' Jungle (*Ridley 9211*, 1898). *Uvaria lobbiana* is a large woody climber with red flowers. Its oblong or oblanceolate laminas have a slightly emarginate base, and are glabrous above with sparse stellate hairs below. *Uvaria lobbiana* is otherwise known from Myanmar, Thailand, Peninsular Malaysia, Sumatra, and Borneo (Sinclair, 1955: 208–210; Turner, 2012).

We also encountered *Elaeocarpus griffithii* (Wight) A.Gray (Elaeocarpaceae) which was also presumed Nationally Extinct in the *Singapore Red Data Book*. However, there are relatively recent collections from Nee Soon (*Nura et al. NK 207*, 26 Jan 1995*; NK 227*, 26 Feb 1995) that were previously overlooked because the species name for these specimens in the database utilised during the listing exercise was "*Elaeocarpus stipularis*". Hence this should be considered more as an error of the listing rather than a true rediscovery (see Chong et al., 2012). Like the more common *Elaeocarpus petiolatus* (Jack) Wall., the apical shoot tips are coated with resin; however, the underside of the dried leaf lamina is not visibly covered with scattered black dots, and the tertiary venation is densely transverse to the midrib, forming rows of neat cells. Corner (1988) also cautioned that it could be easily confused with *Elaeocarpus*

polystachyus Wall. ex Müll.Berol., except that its leaves are generally glabrous and the margins are usually entire or sometimes slightly toothed (rather than hairy and crenate as in *Elaeocarpus polystachyus*).

We also collected *Alangium ridleyi* King, *Gynochthodes rigida* (Miq.) Razafim. & B.Bremer (= *Morinda rigida* Miq.), and *Willughbeia coriacea* Wall., all of which were considered by Chong et al. (2012) to be erroneously extinct listings. *Alangium ridleyi* was later reassessed formally by Wijedasa et al. (2014) as Critically Endangered. In the case of *Willughbeia coriacea*, it was mistakenly considered a synonym of *Willughbeia edulis* Roxb. by Turner (1995), and subsequently presumed Nationally Extinct under this name.

Additions to the flora of Singapore

Securidaca philippinensis Chodat in the Polygalaceae (Tan et al., 2016), and *Cryptocarya nitens* (Blume) Koord. & Valeton and *Litsea resinosa* Blume, both in the Lauraceae (Chong et al., 2016), have been recently reported as new or overlooked records for the flora of Singapore. We also encountered *Hopea ferruginea* Parijs (Dipterocarpaceae) and *Sindora echinocalyx* Prain (Fabaceae), which will be among the new or overlooked records for Singapore from Bukit Timah soon to be reported elsewhere (M.S. Khoo, S.C. Chua, personal communications); *Aglaia erythrosperma* Pannell (Meliaceae), which was already reported by Pannell (2013) for Singapore, although not explicitly stated as a new record; and *Hanguana neglecta* Škorničk. & Niissalo (Hanguanaceae), which was first reported for Singapore by Niissalo et al. (2014). Leong-Škorničková & Boyce (2015) were subsequently able to locate *Hanguana neglecta* in MacRitchie and Bukit Timah but not Nee Soon, although Nee Soon is a historical locality based on re-determined past herbarium records.

The following three additions to the flora of Singapore from our surveys in Nee Soon have not yet been reported:

1. *Aglaia yzermannii* Boerl. & Koord. (Meliaceae)
This is a small rheophytic tree to 5 m tall. The species is easily recognised by its slender twigs and petioles which are sparsely or densely covered in yellowish-brown stellate scales that appear as shiny coppery dots to the unaided eye, and 3−5 linear, linear-lanceolate or narrowly lanceolate leaflets which are sometimes irregularly curved. According to Pannell (2013: 155), this species "appears to be restricted to the banks of relatively deep stretches of otherwise stony, fast flowing rivers" in Peninsular Malaysia. However, our collections of this species were not made from such habitats in Nee Soon.

2. *Dacryodes incurvata* (Engl.) H.J.Lam (Burseraceae)
A small to medium-sized tree. It was once collected from Mandai Road (*Kiah s.n.*, 29 Jul 1940 [SING0053970]) and identified as *Santiria laevigata* Blume, to which it bears

a resemblance except for the leaflet margins that are frequently incurved, terminal buds that are not covered in resin, and petiolules that do not dry black at either ends. The specimen was later re-determined as *Dacryodes incurvata* by K.M. Kochummen. We collected one specimen from one of our plots.

3. *Melanochyla angustifolia* Hook.f. (Anacardiaceae)
This species was also recently collected from the back of the Seletar Range near Old Upper Thomson Road (*Ali s.n.,* 1 Mar 2003 [SING0052434]), which is the eastern side of the Nee Soon catchment. Distinguishable when dried due to a grooved midrib on the underside and wrinkled petiole. The lamina base is cuneate and the leaves are well-spaced and not clustered.

We also collected and identified two varieties that are new to Singapore: *Knema curtisii* (King) Warb. var. *curtisii* (Myristiceae), which was reported by Lim et al. (2016), and *Syzygium claviflorum* (Roxb.) Wall. ex A.M.Cowan & Cowan var. *maingayi* (Duthie) Chantar. & J.Parn. (Myrtaceae). *Syzygium claviflorum* var. *maingayi* can be distinguished from the typical variety by its four-angled and winged twigs (Kochummen, 1978b).

Floristics

By the end of the project, we identified 671 species (or sub-specific taxa, referred to here as 'species' for ease of presentation; Table 4), of which almost all are native (98.4%), and most have been assigned a nationally threatened status (i.e., Nationally Vulnerable, Endangered or Critically Endangered; 72.5%). This does not include the rediscoveries or new records which would require new national conservation assessments. The latter also includes two species which require new assessments due to a recent clarification in their identification (*Trichosanthes elmeri* Merr. had been previously identified as *Trichosanthes celebica* Cogn.; de Wilde & Duyfjes, 2010) or taxonomy (*Utania volubilis* (Wall.) Sugumaran; Sugumaran & Wong, 2014). Slightly fewer than half (43.1%) of the species are trees represented by at least one stem ≥ 5 cm DBH, with similar percentages in the various status categories (Table 4).

The species are from 117 families. While the distribution of species among families in the Nee Soon catchment generally reflects that of the extant Singapore flora (Chong et al., 2011) and especially the forest flora (Turner, 1994), the Myristicaceae is especially well-represented, with 25 species recorded out of the 36 species considered to be native to Singapore (Chong et al., 2009; Lim et al., 2016), of which 22 species occurred within our 40 plots (Table 5). Sixty families are represented by at least one stem ≥ 5 cm DBH, and *Gynotroches axillaris* Blume (Rhizophoraceae) is the most abundant tree species in terms of stem counts, followed by *Baccaurea bracteata* Müll. Arg. (Phyllanthaceae) and *Oncosperma horridum* (Griff.) Scheff. (Arecaceae).

Table 4. Number of species and tree species (≥ 5 cm DBH) from the vegetation plots in each national conservation status (natives) or invasive status (non-natives).

Category	No. of species	No. of tree species
Native	660	285
Not threatened	120	50
Vulnerable	144	55
Endangered	111	53
Crit. End.	232	106
Not assessed		
—Previously presumed Extinct	38	13
—New records	13	8
—Others	2	0
Exotic	8	3
Cultivated only	1	0
Casual	4	2
Naturalised	3	1
Cryptogenic Weed	3	0
Total	**671**	**288**

Discussion

The Nee Soon catchment harbours 53 presumed Nationally Extinct species according to the most recent *Singapore Red Data Book*, as well as 11 species records and two varieties which are new to or had been overlooked in previous checklists of the Singapore flora (e.g., Chong et al., 2009). Our findings reinforce published opinions (e.g., Turner et al., 1994; Turner et al., 1996a) that the Nee Soon Swamp Forest merits the highest conservation priority in Singapore, and is of comparable floristic value to the more well-known Bukit Timah Nature Reserve.

It does not necessarily follow that one should automatically confer upon rediscovered species the status of Critically Endangered. One example is *Uvaria curtisii*, which has been collected from multiple localities in the nature reserves in recent years. Another example from previous rediscoveries is *Grenacheria amentacea* (C.B.Clarke) Mez, which appears to be fairly widespread in Nee Soon (Table 3) and also in the part of the Central Catchment Nature Reserve along Mandai Road (K.Y. Chong, personal observations). It is likely that these species belong to poorly documented

Table 5. Top ten families of vascular plants in the Nee Soon catchment according to the total number of species, the number of tree species (≥ 5 cm DBH), stem abundance, and total basal area of trees. Ranks are given in superscript next to the counts.

Family	No. of species	No. of tree species	No. of stems	Total basal area
Rubiaceae	41 [1]	15 [5]	136 [3]	3.93% [8]
Annonaceae	40 [2]	12 [7]	32	2.00%
Myrtaceae	31 [3]	20 [3]	124 [5]	6.80% [4]
Phyllanthaceae	28 [4]	21 [2]	217 [1]	4.03% [7]
Moraceae	28 [5]	9 [9]	23	1.70%
Myristicaceae	26 [6]	23 [1]	126 [4]	8.26% [3]
Euphorbiaceae	22 [7]	14 [6]	145 [2]	5.18% [6]
Lauraceae	22 [7]	17 [4]	56 [9]	2.54%
Apocynaceae	19 [9]	6	32	2.36%
Fabaceae	17 [10]	6	35	1.53%
...				
Dipterocarpaceae	12	11 [8]	33	6.10% [5]
Burseraceae	11	9 [9]	27	1.27%
…				
Clusiaceae	10	8	53 [10]	1.18%
…				
Anacardiaceae	8	7	73 [7]	8.95% [1]
Arecaceae	8	2	73 [7]	3.19% [10]
…				
Sapindaceae	7	4	41	3.59% [9]
…				
Rhizophoraceae	3	3	112 [6]	2.84%
…				
Combretaceae	1	1	1	8.67% [2]

or difficult-to-identify taxa that tend to go unnoticed by generalist collectors. While they would almost certainly qualify as threatened, a proper nation-wide conservation assessment can be made only after targeted search efforts with a broader geographic coverage has been carried out.

Given that most of our collections are sterile, it is possible that some of our identifications may be erroneous. The collection numbers of most of the voucher specimens of the rediscovered species or new records deposited in the herbaria (see Appendix 1) therefore contain the plot numbers so that the respective individuals may be revisited for flowers or fruits. All stems ≥ 10 cm DBH within our plots were also mapped to positions of 0.5 m resolution so some of the tree species can also be tracked down to the individuals we encountered; these maps, the DBH measurements, and the geographic coordinates of the plots, are available upon request.

The floristics presented in Turner et al. (1996a) were based largely on three clusters of plots with a total area of 0.6 ha. On the other hand, our study consisted of 40 plots sampled across the different elevation zones throughout the Nee Soon catchment, and totalled 1.6 ha. Our sampling is more extensive, and less biased than past opportunistic botanical collections, and therefore the floristic composition we present here is the most representative of the catchment so far—with the caveat that we focused more on the forest understorey and trees, and thus may have under-sampled canopy lianas (which were incompletely identified due to lack of access to leaves), and crown epiphytes. More detailed analyses of soil, hydrology, and the plant communities will be presented in future manuscripts.

In Singapore, the phrase 'filling of swamps' is evocative of the city-state's determination to survive at all costs during its early post-independence years, and is associated with its industrial and developmental success today. Singapore is not unique in its past treatment of swamps; economic growth is a key driver of the loss of wetlands worldwide (van Asselen et al., 2013), with two-thirds of the world's wetlands having been lost since 1900 (Davidson, 2014). On the one hand, the recent cache of rediscoveries and new records from Singapore's last substantial tract of freshwater swamp forest in the Nee Soon catchment provides some relief that some of this natural heritage is safe within a protected area, and hope that more might be found; on the other hand, it is sobering to imagine what other biological treasures must have been lost when swamp forests such as those at Mandai and Jurong were inundated or reclaimed. Going forward, no effort must be spared to ensure that the Nee Soon swamp forest will continue to persist, and perhaps some effort should even be made to recreate this habitat type elsewhere in Singapore.

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Appendix 1. Collection numbers for rediscoveries or new records mentioned in the text and/or Table 3, as well as those rediscovered prior to our study (Table 1) that we also found in our plots. All specimens are deposited at the Herbarium, Lee Kong Chian Natural History Museum, National University of Singapore (SINU).

Species	Collection number(s)
Actinodaphne macrophylla (Blume) Nees	*NSSF1-Q1000-5066, NSSF2-Q203aU114, NSSF2-Q204T27*
Aglaia elliptica Blume ssp. *elliptica*	*NSSF2-Q209U80, NSSF2-Q4T59*
Aglaia erythrosperma Pannell	*NSSF2-Q112U61*
Aglaia tenuicaulis Hiern	*NSSF2-Q111U132, NSSF2-Q203aU86*
Aglaia yzermannii Boerl. & Koord.	*NSSF2-Q107U05, NSSF2-Q213U82*
Alangium ridleyi King	*NSSF2-Q4T30*
Baccaurea macrophylla (Müll.Arg.) Müll. Arg.	*NSSF2-Q204T16, NSSF2-Q213U100*
Callistopteris superba (Backh. ex T.Moore) Ebihara & K.Iwats,	*NSSF2-Pte32*
Cryptocarya nitens (Blume) Koord. & Valeton	*NSSF2-Q1T54, NSSF2-Q213U72, NSSF2-Q205U45*
Dacryodes incurvata (Engl.) H.J.Lam	*NSSF2-Q206T55*
Dalbergia parviflora Roxb.	*NSSF1-Q100-962, NSSF2-Q1U09*
Dendrobium aloifolium (Blume) Rchb.f.	*NSSF1-Q300-502*
Deplanchea bancana (Scheff.) Steen.	*NSSF2-Q203aT21*
Dichapetalum sordidum (Hook.f.) Leenh.	*NSSF1-Q1C0-1064*
Dioscorea orbiculata Hook.f. var. *tenuifolia* (Ridl.) Thapyai	*NSSF2-Q102U114, NSSF2-Q204U105, NSSF2-Q2U04, NSSF2-305U36, NSSF2-Q308U109*
Dioscorea stenomeriflora Prain & Burk.	*NSSF2-Q101U16*
Dracaena singapurensis Ridl.	*NSSF2-Q101U53, NSSF2-109U99*
Elaeocarpus griffithii (Wight) Gray	*NSSF2-Q104U54, NSSF2-Q111T58*
Fagraea splendens Blume	*NSSF2-Q308aU81*
Freycinetia javanica Blume	*NSSF1-Q4C0-866, NSSF2-Q4U129*
Friesodielsia glauca (Hook.f. & Thomson) Steen.	*NSSF2-Q10U126*
Globba pendula Roxb.	*NSSF2-Q308aU39*
Grenacheria amentacea (C.B.Clarke) Mez	*NSSF2-Q2U41*
Gynochthodes rigida (Miq.) Razafim. & B.Bremer	*NSSF2-Q319aU80*
Hanguana neglecta Škorničk. & Niissalo	*NSSF2-18*
Helicia excelsa (Roxb.) Blume	*NSSF2-Q204U54, NSSF2-Q204U87*
Hopea ferruginea Parijs	*NSSF2-Q509U12, NSSF2-Q509T46, NSSF2-Q509T53*

Appendix 1. Continuation.

Species	Collection number(s)
Hypserpa nitida Miers	*NSSF2-Q206U77, NSSF2-Q4U121, NSSF2-Q4U144*
Knema curtisii (King) Warb. var. *curtisii*	*NSSF2-Q111U26, NSSF2-Q203aT40*
Knema glaucescens Jack	*NSSF2-Q204U50, NSSF2-308aT07*
Lindsaea repens (Bory) Thwaites var. *pectinata* (Blume) Mett.	*NSSF2-Pte2*
Litsea resinosa Blume	*NSSF2-Q105U46, NSSF2-Q307U66, NSSF2-Q311aU120*
Melanochyla angustifolia Hook.f.	*NSSF2-Q112T31, NSSF2-Q3U155*
Meliosma pinnata (Roxb.) Maxim. ssp. *ridleyi* (King) Beusekom	*NSSF2-Q504T46a*
Neesia malayana Bakh.	*NSSF2-Q112T48, NSSF2-Q9T10*
Nephelium laurinum Blume	*NSSF2-Q206U140, NSSF2-Q4U120*
Pinanga simplicifrons (Miq.) Becc.	*NSSF2-94*
Pterisanthes cissioides Blume	*NSSF2-Q107U82, NSSF2-Q308aU116*
Rourea acutipetala Miq. ssp. *acutipetala*	*NSSF2-Q101U100, NSSF2-Q2U35, NSSF2-Q404aU43, NSSF2-Q8U96*
Salacia maingayi M.A.Lawson	*NSSF1-Q400-826*
Securidaca philippinensis Chodat	*NSSF2-Q102T27, NSSF2-Q102U124, NSSF2-Q8U72*
Sindora echinocalyx Prain	*NSSF2-Q101U111*
Strychnos axillaris Colebr.	*NSSF1-Q100-1070*
Syzygium claviflorum (Roxb.) Wall. ex A.M.Cowan & Cowan var. *maingayi* (Duthie) Chantar. & J.Parn.	*NSSF2-Q217U14, NSSF2-Q302U71*
Syzygium glabratum (DC.) Veldkamp	*NSSF2-Q101U131, NSSF2-Q111T37, NSSF2-Q203aT29, NSSF2-Q206U42*
Syzygium kunstleri (King) Bahadur & R.C.Gaur	*NSSF2-Q104T38*
Syzygium leptostemon (Korth.) Merr. & L.M.Perry	*NSSF2-Q111T53, NSSF2-Q111U116*
Syzygium pseudocrenulatum (M.R.Hend.) I.M.Turner	*NSSF2-Q104U35, NSSF2-Q204U78*
Syzygium scortechinii (King) Chantar. & J.Parn.	*NSSF2-Q111U122*
Trigoniastrum hypoleucum Miq.	*NSSF2-Q101T40, NSSF2-Q101U61*
Uncaria attenuata Korth.	*NSSF2-Q10U110*
Uvaria curtisii King	*NSSF2-Q302U74, NSSF2-Q504U89*
Uvaria lobbiana Hook.f. & Thomson	*NSSF2-Q4U113*
Willughbeia coriacea Wall.	*NSSF2-Q8U111*