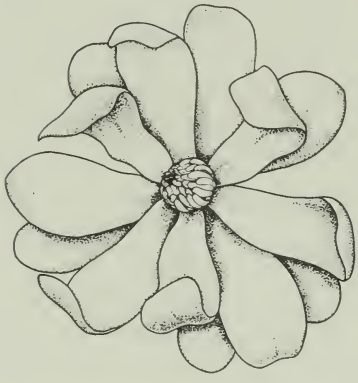

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Additions to the Flora of Singapore, III[1].

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Abstract

Eleven species are added to the flora of Singapore as presented by Turner (1993). *Lecanopteris sinuosa* (Polypodiaceae) was mistakenly omitted from that list. Records of *Dischidia complex* (Asclepiadaceae), *Grenacheria fulva* (Myrsinaceae) and *Microcos globulifera* (Tiliaceae) were also overlooked. *Mangifera paludosa* (Anacardiaceae) has recently been described from a pre-War Singapore collection. *Combretum tetralophum* (Combrebaceae), *Korthalsia flagellaris* (Palmae), *Pouteria linggensis* (Sapotaceae) and *Sindora coriacea* (Leguminosae) are native species that have newly been collected for the first time in Singapore. The successful naturalization of *Justicia procumbens* (Acanthaceae) and *Macroptilium atropurpureum* (Leguminosae) is reported.

Introduction

In this series of articles on the flora of Singapore, we have taken the list published by Turner (1993) as the reference point for the composition of the flora. Subsequently species found growing wild in Singapore that are not included in the list have been reported. In the current paper eleven more species are added to the list. Nomenclature follows Turner (1995) wherever possible.

1. *Combretum tetralophum* C.B. Clarke Combretaceae

Large liana or scandent shrub with spikes of small sweet-smelling flowers. The fruits are ovoid to 4 cm long, with four distinct, longitudinal, sharp-edged wings or ridges. The species is characteristic of lowland river margins and back mangroves and is probably dispersed by water. It occurs from Indo-China to the Pacific, though it is absent from the Philippines (Exell, 1954 p. 541). Its occurrence in Singapore is therefore not surprising, but it

[1]Continued from *Gardens' Bulletin Singapore* **42** *(1994) 131-135.*

has eluded detection for many years, until recently when it was collected in fruit on Pulau Semakau (*H.T.W. Tan et al. S1005*, 27 September 96 SINU).

2. *Dischidia complex* Griff. Asclepiadaceae

A twining epiphyte with pitcher-like leaves (Rintz, 1980 p. 97) found in lowland forest. It is known from the south of the Malay Peninsula and Borneo. At least one Singapore collection is known (*E.J.H. Corner s.n.*, January 1933, Jurong SING), but it is probably exinct today.

3. *Grenacheria fulva* (Mez) Airy Shaw Myrsinaceae

A climbing shrub (in Stone 1989 p. 279 as *Embelia fulva* Mez) it was once collected (*E.J.H. Corner SFN 26195,* 5 March 1933 SING) from the swamp forests that covered Jurong before development of the area took place. The species is endemic to the Malay Peninsula and Borneo, and is probably now extinct in Singapore.

4. *Justicia procumbens* L. Acanthaceae

Small prostrate herb, creeping, to 60 cm long, with small, terminal spikes of zygomorphic flowers which have pale pink-purple corollas with darker markings. It is included in Mohamad Soerjani et al. (1987 p. 28) under its synonym *Rostellularia sundana* Bremek. It was first collected in Singapore by Ahamed (16 October 1954) along Mandai Road. It still occurs in that area (*I.M. Turner 93-6,* 3 January 1993, Mandai Lake Road SINU), but recently appears to have become more common. It is a frequent weed of short mown grass around Holland Village, and has also been seen along Alexandra Road. It appears to be another example of a weedy species filling an empty niche in urban Singapore.

5. *Korthalsia flagellaris* Miq. Palmae

Large clustering rattan to 40 m in length readily distinguished by its almost unarmed stems, and bright green leaflets which are covered with a red-brown indumentum on the lower surface (Dransfield, 1979 p. 42). The leaflets are sessile, but the base of the lamina is tightly, longitudinally folded forming a flexible petiole-like connection to the rachis. Dransfield reports this species as being confined to peat swamp forest. In Singapore it has recently been found in the Nee Soon swamp forest (*D.H. Murphy s.n.*, 23 December 1994 SING; *I.M. Turner & P.P. Kumar 18* SINU), which is

freshwater swamp with relatively little peat accumulation. *Korthalsia flagellaris* is found in the Malay Peninsula, Sumatra and Borneo, and has presumably been overlooked in Singapore until now.

6. *Lecanopteris sinuosa* (Wall. ex Hook.) Copel. Polypodiaceae

This species was mistakenly omitted from the Singapore species list (Turner 1993). It is the commoner of the ant-inhabited epiphytic ferns to be found in Singapore (Johnson, 1977 p. 50 under the synonym *Phymatodes sinuosa* (Wall. ex Hook.) J.Sm.).

7. *Macroptilium atropurpureum* (DC.) Urban Leguminosae

A twining perennial herb with hairy trifoliate leaves that appear distinctly silvery and with very dark purple, almost black, flowers. It is native of tropical America, but has been used throughout the tropics as a forage and soil-binding plant (Jones & 't Mannetje, 1992 pp. 155-156). It has become quite common on reclaimed land on Pulau Tekong where it was collected recently (*H.T.W. Tan et al. T2033*, 20 August 1996 SINU). It seems highly likely that this species will join its congener *Macroptilium lathyroides* (L.) Urban as a frequent colonist of dry open waste ground in Singapore.

8. *Mangifera paludosa* Kosterm. Anacardiaceae

This species was recently described by Kostermans (Kostermans & Bompard, 1993 p. 41) with *Corner SFN 26193* collected from Jurong as the holotype. It is a tree to 30 m tall found in freshwater swamp forest, often behind mangroves and is known from the Malay Peninsula and Sumatra. There can be little doubt that the species is no longer to be found in Jurong.

In the same work, Kostermans also described *Mangifera subsessilifolia* based on a Singapore type collected at Bukit Timah. However, this species is known only from sterile material. Kostermans also referred a sterile collection from the former swamp forest at Mandai Road (*Kiah s.n.* 24 July 1940 SING) to *Mangifera magnifica* Kochummen, a species not previously recorded from Singapore. We leave final acceptance of these species to whomever prepares the account of the Anacardiaceae for the Angiosperm Flora of Singapore.

9. *Microcos globulifera* (Mast.) Burret Tiliaceae

This small tree of lowland forest (Kochummen, 1972 p. 397 under the

synonym *Grewia globulifera* Mast.) has escaped the notice of compilers of the Singapore flora. It has been collected in the Botanic Gardens' Jungle (*Hassan SFN 36267* 25 April 1939 SING) and Bukit Timah (*Ngadiman SFN 36416* 4 May 1939 SING). The species is endemic to the Malay Peninsula.

10. *Pouteria linggensis* (Burck) Baehni Sapotaceae

A tree to 20 m tall found on rocky shores and occasionally inland (Ng, 1972 p. 436 under the synonym *Planchonella linggensis* (Burck) Pierre). The species is found throughout Malesia and was recently discovered on Pulau Sakijang Pelepah (Lazarus Island) (*H.T.W. Tan et al.* LI001 SING).

11. *Sindora coriacea* (Baker) Prain Leguminosae

A big forest tree reaching more than 30 m in height, distinguished from the other Malay Peninsula species of the genus by its shiny leaflets which are glabrous beneath and its unarmed pods. The pods shown in Fig. 1 were photographed in Bukit Timah Nature Reserve by Ali Ibrahim, but no herbarium specimen was made. Later he collected a fertile specimen from Mandai, Central Catchment Nature Reserve (*Wong, Ali & Chew 16*, 23 Nov 1992 SING). A further sterile collection (*A.H.B. Loo et al. 83*, 29 Oct 1996 SING) was gathered at Bukit Kallang. The species is common

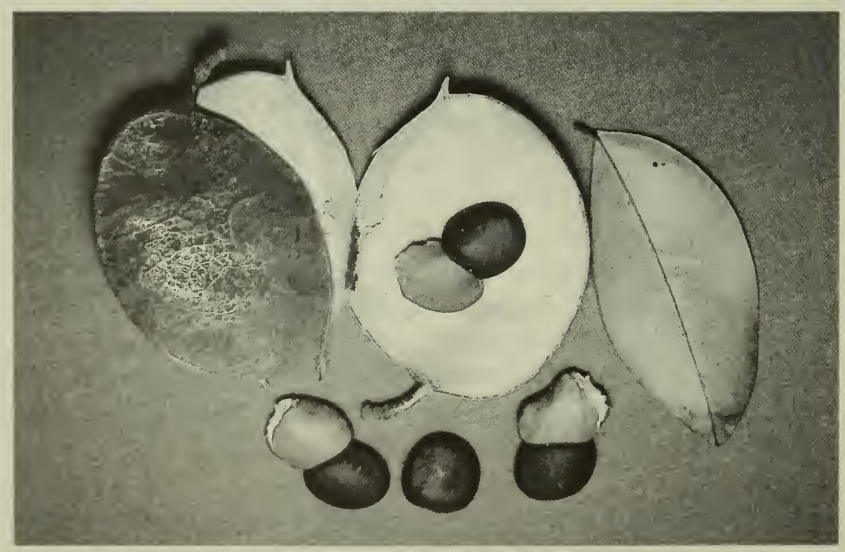

Figure 1. Pods and seeds of *Sindora coriacea* found in Bukit Timah Nature Reserve, Singapore.

throughout Malaya and also occurs in Sumatra and Borneo. Presumably its apparent rarity and confusion with other species of *Sindora* have hitherto led to it being overlooked in Singapore.

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Root Hemi-parasitism In Malayan Olacaceae

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Abstract

Six species of Olacaceae found in the Malay Peninsula were investigated for parasitism. Root parasitism was observed only in *Olax psittacorum* and *Ximenia americana* var. *americana* but not in *Strombosia javanica, Scorodocarpus borneensis, Ochanostachys amentacea* and *Erythropalum scandens*. Haustoria of the two parasitic species were found attached to a number of hosts indicating that they are non-host specific. Anatomy of the haustoria revealed that the suckers of the haustoria form a cup-like structure around the stelar region of the host roots.

Introduction

Hemi-parasitism is known to occur among families of the Santalales. Nevertheless, the extent to which parasitism occurs within the Olacaceae has not been comprehensively investigated (Fineran, 1991). Cronquist (1981) stated that most genera of Olacaceae are parasitic, while Whitmore (1973) in his revision of Malayan Olacaceae, remarked that none is parasitic. Corner (1988) mentioned that the roots of *Ximenia americana* are parasitic including on roots of its own kind, while Backer and Bakhuizen (1965) stated that the Olacaceae of Java are sometimes parasitic. However, there is insufficient evidence to substantiate these claims. A review of literature shows that the only published work on parasitism in Olacaceae reported from Malesia is that on *Olax imbricata* from the Philippines (Herbert, 1922). Fineran (1991) cited geographical inaccessibility as the reason why the Olacaceae was poorly studied. Field work was therefore undertaken in Peninsular Malaysia to give a better understanding of the occurrence of hemi-parasitism in the Olacaceae.

Materials and Methods

Parasitism can only be demonstrated by the presence of haustoria and their penetration into the host roots. In the case of root parasites, the haustoria occur below the soil surface so are not easy to locate. Indeed, a

cangkul and shovel were used to unearth the roots. The root systems were then examined carefully for the presence of haustoria and host plants to which the haustoria were attached were identified as far as possible. Plants in their natural habitat as well as those cultivated at Rimba Ilmu (Botanic Garden), University of Malaya were used in the study. The following is the list of plants studied.

Erythropalum scandens Blume.
Bukit Lagong Forest Reserve, Selangor; Telok Cempedak, Kuantan, Pahang *(KLU 041342, KLU 041344, KLU 141349)*

Ochanostachys amentacea Masters
Rimba Ilmu, University of Malaya, Kuala Lumpur
(KLU 041331, KLU 041333, KLU 041345)

Olax psittacorum (Willd)Vahl.
Kampung Sungai Baging, Trengganu
(KLU 041337, KLU 041338)

Strombosia javanica Blume.
Bukit Lagong Forest Reserve, Selangor
(KLU 041341, KLU 041340, KLU 041339)

Scorodocarpus borneensis (Baill.) Becc.
Bukit Lagong Forest Reserve, Selangor
(KLU 041045, KLU 041382, KLU 041329)

Ximenia americana L. var. *americana* Defilipps
Blue Lagoon, Port Dickson, Negeri Sembilan
(KLU 041339, KLU 041340, KLU 041341)

Haustoria found during the study were preserved in 50% FAA (50% ethanol:formalin:acetic acid 18:1:1) for further morphological and anatomical investigations. They are also deposited in the University of Malaya Herbarium (KLU). Seedlings of species not already represented in Rimba Ilmu were brought back and grown there.

Results and Discussion

Only two of the six species of Olacaceae studied were found to be hemiparasitic, namely *Olax psittacorum* (Fig 1) and *Ximenia americana* var. *americana* (Fig 2).

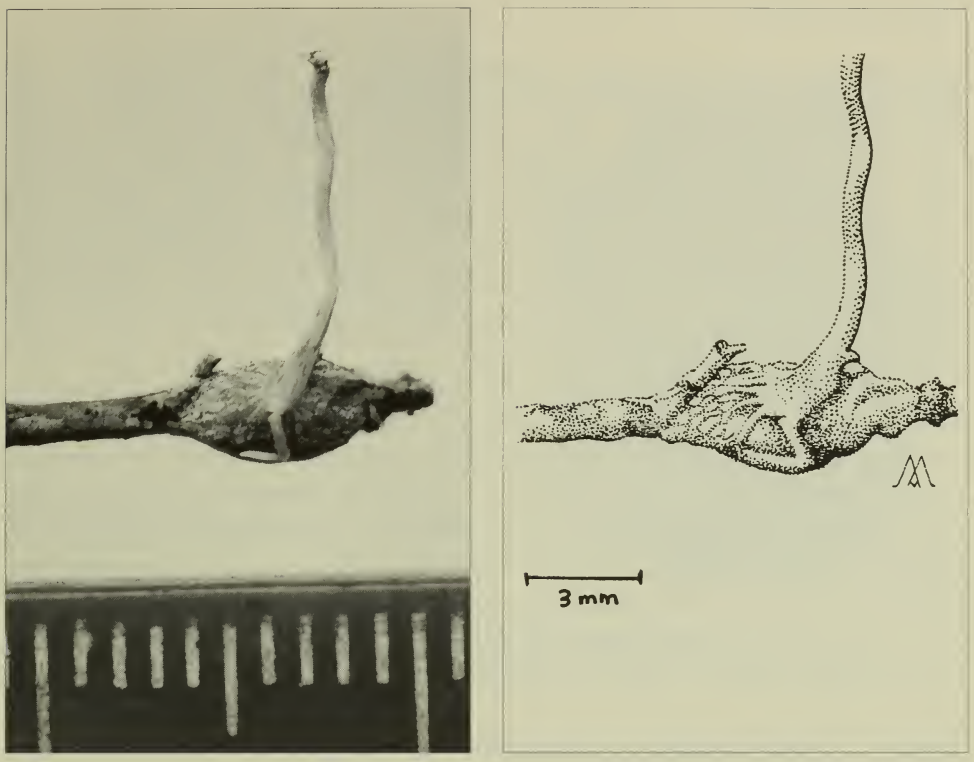

Figure 1. Haustorium of *Olax psittacorum* invading the root of its own species.

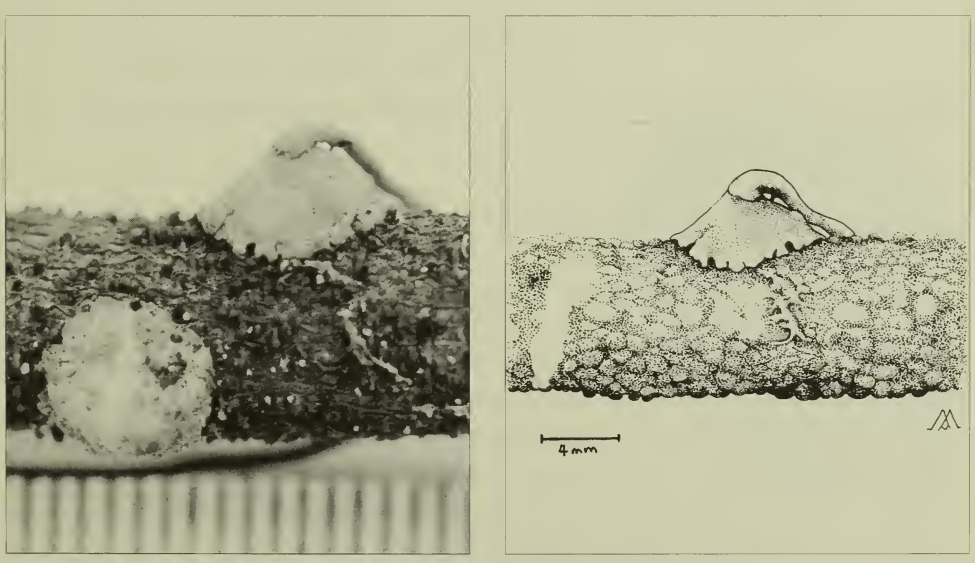

Figure 2. Haustorium of *Ximenia americana* var. *americana* invading the root of *Pongamia pinnata.*

Haustoria and host

Both primary and secondary haustoria occur in *Olax psittacorum* and *Ximenia americana* var. *americana*. The haustoria totally or partially encircle the host roots depending upon whether the roots are small or large, respectively. The haustoria of *Olax psittacorum* are more or less dome-shaped while those of *Ximenia americana* var. *americana* are more flattened and disc-like during the early stage but later become dome-shaped. Haustoria size ranged from about 1–20mm while their colour depends on age. In general, the haustoria darken with age. This may be due to an accumulation of phenolic compounds.

The haustoria of both *Olax psittacorum* and *Ximenia americana* var. *americana* invade the roots of other plants of their own species in the same way that Herbert (1922) reported in *Olax imbricata*. This further confirms the remark made by Corner (1988) for *Ximenia americana* var. *americana*. Self-parasitism probably arose out of the need to increase the efficency in the use of limited water resource, especially when the hemi-parasites are found in a hostile environment. In general, it appears that both species are non-host specific judging from the number of hosts they can attack (Table 1). However, only the roots of dicotyledons are attacked by the haustoria.

Table 1 : Plants invaded by the haustoria of *Olax psittacorum* and *Ximenia americana*.

Olax psittacorum	*Ximenia americana*
Aglaia sp. (Meliaceae)	*Pongamia pinnata* (Leguminosae)
Tetracera sp. (Dilleniaceae)	*Terminalia catappa* (Combretaceae)
Psychotria sp. (Rubiaceae)	
Anacardium occidentale (Anacardiaceae)	

Anatomical sections of the haustoria of *Olax psittacorum* and *Ximenia americana* var. *americana* reveal that the sucker at the distal end of the vascular core forms a structure that is appressed to the stele of the host roots (Fig. 3 & 4). The suckers are only connected to the xylem but not the phloem. The location and arrangement of the conducting vascular cells in both *Olax psittacorum* and *Ximenia americana* var. *americana* are essentially similar. In *Olax psittacorum*, only one strand of the conducting tissue links the host to the parasite and occupies a central position in the sucker whereas for *Ximenia americana* var. *americana*, there exist two strands of conducting tissue and both strands are at the periphery.

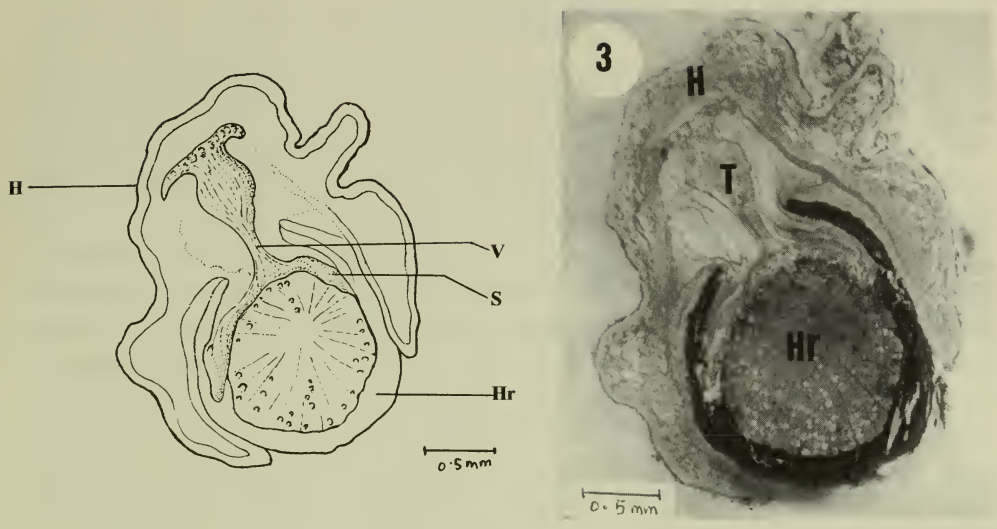

Figure 3. Cross-sectizon of the haustorium of *Olax psittacorum.*
H-haustorium; Hr - host root; V-vascular core; S-Sucker; T-vascular core

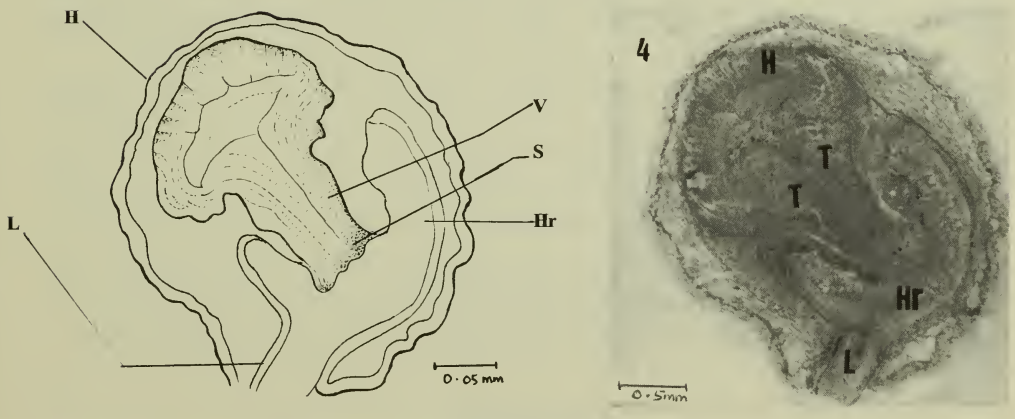

Figure 4. Cross-section of the haustorium of *Ximenia americana* var. a*mericana*. H-haustorium; Hr - host root; L-lateral root; V-vascular core; S-Sucker; T-vascular core

Correlation between parasitism and habitat in Olacaceae

The occurrence of parasitism among different families and orders demonstrates that this mode of nutrition has evolved independently many times during the evolution of angiosperms (Nickrent and Franchina, 1990; Fineran, 1991). Parasitism might have developed among different taxa due to similar habitat conditions. This might occur where certain nutrients and water were scarce, and especially under circumstances favourable for the development of organic connections between plants (Fineran, 1991).

The two parasitic species, *Olax psittacorum* and *Ximenia americana* var. *americana*, thrive well in dry, sandy coastal areas while the non-parasitic members are found in humid evergreen forest. Most hemiparasitic taxa of the Santalales prefer somewhat open habitats with extreme conditions, e.g. dry or harsh (Fineran, 1991). Parasitism may have arisen out of the need to adapt in a water-deficient habitat. In fact, the dry, sandy habitat along the coast of the Malay Peninsula supports a high number of other parasitic plants from different famillies, namely, *Champereia manillana* (Opiliaceae), *Dendrotrophe* spp. (Santalaceae) and *Cassytha filiformis* (Lauraceae).

The fact that there is only connection between the haustorium and the xylem in both *Olax psittacorum* and *Ximenia americana* var. *americana* coupled with their occurrence in only dry habitats demonstrates that hemi-parasitism is one of the adaptive features that may increase the efficiency in the use of water. This is also found to be true in other hemi-parasites (Pate *et al.*, 1990a, 1900b; Fineran, 1991). However, there is no co-relationship between type of root system and life-form with hemi-parasitism as suggested by other workers such as Pate *et al.* (1990a, 1990b) and Fineran (1991). For example, *Olax psittacorum* has a shallow and extensive root system and is a scrambling shrub, while *Ximenia americana* var. *americana* has a root system quite deeply rooted and it is a tree up to 5 m high.

Within the haustoria of root parasites, there are unusual xylem conducting cells known as graniferous (granule-containing) tracheary elements (Fineran, 1985). Fineran (1985) noted that the nature of the granules in Olacaceae is not consistent and varies from protein in one genus to starch in another. On the other hand, the nature of granules in other families of the Santalales is very consistent. Fineran suggested that this showed that the Olacaceae is an unnatural family and with different treachery elements, root parasitism has arisen at least twice in the family.

Conclusion

This study shows that only some species of the Olacaceae are hemi-parasitic, namely *Olax psittacorum* and *Ximenia americana* var. *americana,* and that they are non-host specific and that self-parasitism occurs.

Acknowledgements

I am indebted to Dr. N. Prakash, University of New England, Australia, Dr. Noorma Wati Haron and Prof. Haji Mohamed Abdul Majid, Head of Botany Department, University of Malaya for their comments. Thanks are also due to Mr. Mohamed Akip and Mr. Joseph Pao for the illustrations provided. This paper reports part of an MSc thesis submitted to the University of Malaya, Kuala Lumpur, which was supervised by Dr. Noorma Wati Haron. Financial grants from Vote F 150/94 (University of Malaya) and R & D 1-07-04-049-04 (Malaysian government) are gratefully acknowledged.

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A Botanical Survey of Sungei Buloh Nature Park, Singapore

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Abstract

A total of 249 wild vascular plant species (15 ferns, 1 gymnosperm, 233 angiosperms) were collected on a succession of trips between 1991 and 1993 to the Sungei Buloh Nature Park. The current flora includes mangrove and beach or coastal forest species but the majority are early successionals, native and exotic weeds and species associated with cultivation. Earlier collections from the Herbarium, Singapore Botanic Gardens, dating from the late 1880s to the early 1900s were also included and these totalled 76 (1 club moss, 7 ferns and 68 angiosperms). The original flora was very different and consisted mainly of lowland, or beach or coastal forest, and mangrove species. The great change in species composition and the high number of weedy species in the current flora reflect major man-made changes to the environment. Combining both historical and recent collections, the wild vascular plant flora of Sungei Buloh Nature Park totals 318 species (1 club moss, 21 ferns, 1 gymnosperm and 295 angiosperms).

Introduction

Sungei Buloh Nature Park, including Pulau Buloh, consists of 87 ha of land (Fig. 1). A botanical survey was conducted to provide baseline information for future reintroduction or introduction programmes.

Site

Sungei Buloh Nature Park is situated in the north-western coast of Singapore island (N1°42'53.5" E103°43'30.8"). The proposal to set up this park and its infrastructure was approved by the Master Plan Committee

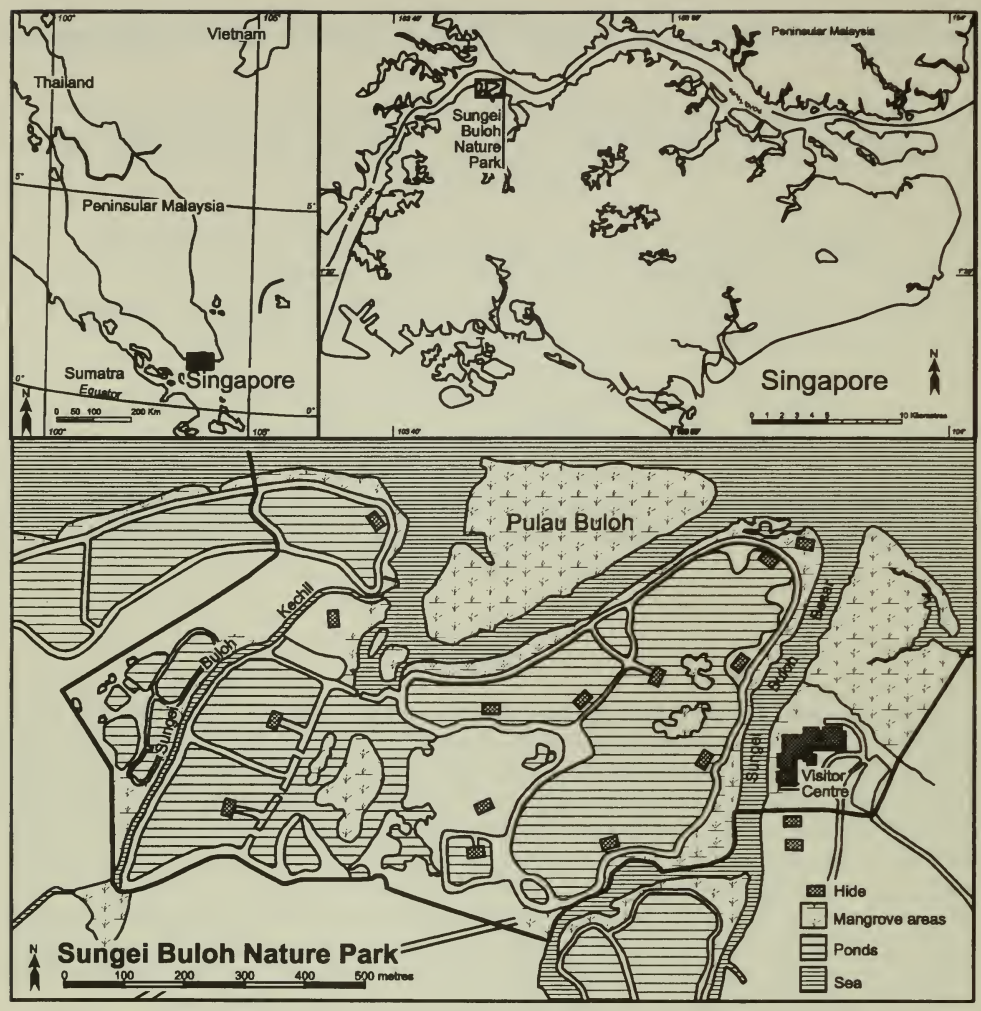

Figure 1. Maps of Singapore and Sungei Buloh Nature Park. Above left, position of Singapore in relation to Peninsular Malaysia; above right, map of Singapore showing the position of Sungei Buloh Nature Park; bottom, Sungei Buloh Nature Park.

on the 29th March 1990 and the park was officially opened on the 6th December 1993.

The park is a wetland area and consists of three main parts: the reserve proper, the Visitor Centre area and Pulau Buloh, an island north of the reserve area (Fig. 1). The river, Sungei Buloh Besar separates the reserve proper from the Visitor Centre. Both Pulau Buloh and the Visitor Centre area consist mainly of mangrove as well as man-made brackish and freshwater ponds in the reserve proper. The site was marked for preservation by the Singapore government as it is used by large numbers of coastal birds, including the black-crowned night-heron (*Nycticorax*

nycticorax), common greenshank (*Tringa nebularia*), common redshank (*Tringa totanus*), curlew sandpiper (*Calidris ferruginea*), grey heron (*Ardea cinerea*), marsh sandpiper (*Tringa stagnatilis*), Pacific golden plover (*Pluvialis fulva*) and whimbrel (*Numenius phaeopus*).

History of Land Use

According to the 1890 Straits Settlement Government Gazette Reports of the Botanic Gardens, the Sungei Buloh area was a forest reserve from 17th April 1890 and "Consists entirely of mangrove swamp". However, this "area of 1,128 acres, 3 roods (sic) and 18 poles, more or less" (approximately 457 ha) ceased to be a forest reserve on 4th April 1938 (Straits Settlement Government Gazette, 1938).

When first designated as forest reserve in 1890, the area appeared to be entirely mangrove. Records as to when prawn and fish ponds were constructed are not available but with the development of farms, the mangroves were cleared. Native species were replaced by cultivated species for consumption by the farmers or their livestock. The farms and ponds were abandoned in 1989, when the Government took over the site, after which time early successional and weedy species invaded the area.

Methods

The present survey consisted of collection trips made on 22nd May, 30th August and 7th October 1991 and 27th September and 13th October 1993. The park was divided into sectors where the collecting teams concentrated their efforts. Representative specimens of all wild species, whether sterile or not, were collected and made into herbarium specimens which were deposited in the Herbarium, School of Biological Sciences, The National University of Singapore (SINU). Specimens were identified by comparison with descriptions in floras or recent revisions, as well as with named specimens in the Herbarium, Singapore Botanic Gardens (SING). Historical collections from Sg. Buloh at SING were examined. Nomenclature and habitat data mostly follow those of Turner (1995).

Observations and Discussion

A total of 249 wild vascular plant species were collected in the survey (Appendix 1) and included 15 ferns, 1 gymnosperm (*Podocarpus polystachyus*) and 239 angiosperms.

Most plants are characteristic of a highly disturbed environment. The Sg. Buloh area presumably became highly disturbed when the prawn and fish farms were established and the mangrove cleared and earth excavated to create the ponds. Not much regeneration could take place as the farmers would have to keep the mangroves out of the ponds and the bund areas. Together with human settlement, there would be planting of vegetable crops, fruit trees, spice, flavouring and ornamental plants.

When the government took over the site in 1989, soil was brought in from other parts of Singapore. The latter is the most likely seed source for the large number of exotic and native weed species, such as *Ageratum conyzoides, Kyllingia polyphylla, Panicum maximum* and *Pityrogramma calomelanos*. Exotic pioneer tree species include *Acacia auriculiformis*, *Manihot glaziovii*, *Muntingia calabura* and *Spathodea campanulata*. If left unchecked, *Acacia auriculiformis* may dominate those areas which are not flooded at high tide.

Weed species considered native also make up a significant part of the flora and include *Centella asiatica*, *Eulophia graminea*, *Imperata cylindrica* and *Vernonia cinerea*.

Secondary forest would have developed after the clearance of the original primary forest. Its species include *Alstonia angustiloba*, *Melastoma malabathricum*, *Trema* spp. and *Vitex pinnata*.

The beach or coastal forest and mangrove species are probably remnants of the original forest. Mangrove and its components include *Acrostichum* spp., *Bruguiera* spp., *Hibiscus tiliaceus* and *Rhizophora* spp.

Species escaped or persisting from cultivation include vegetables such as *Coccinia grandis*, *Ipomoea batatas* and *Manihot esculenta*, fruit trees such as *Annona muricata*, *Artocarpus heterophyllus*, *A. integer*, *Carica papaya*, *Durio zibethinus* and *Psidium guajava*, spice or flavouring plants such as *Murraya koenigii* and *Pandanus amaryllifolius*, as well as ornamental plants such as *Celosia argentea*, *Dieffenbachia seguine*, *Tabebuia rosea* and *Vernonia elliptica*.

Based mostly on the conservation status ascribed by Turner *et al.* (1995), 2 endangered species (*Cassine viburnifolia* and *Podocarpus polystachyus*), 6 vulnerable species, 58 rare species and 90 common species were collected. For the exotic species, 66 are naturalized and 28 associated with cultivation, making up about 37.8% of the total vascular plant flora. This indicates the great disturbance in the area.

There are 12 fern families, each with only one species except for the Pteridaceae with three, and the Polypodiaceae with two. The single gymnosperm is *Podocarpus polystachyus*. Angiosperms dominate the park. The largest ten families, in descending order are: Gramineae (25 species), Papilionaceae (16), Compositae (15), Cyperaceae (12), Euphorbiaceae (11),

Mimosaceae (9), Rubiaceae (9), Convolvulaceae (8), Moraceae (7) and Verbenaceae (7). Again, weed and secondary forest species are the main representatives of these families. Other families had six or fewer species and 37 families had only one species each.

Appendix 2 lists the plants collected by H.N. Ridley, J.S. Goodenough, and L.C. Corporal between 1889 and 1911. This list is by no means representative of the whole area as they comprise opportunisitic collections in the area. A total of 76 vascular plant species were recorded with one club moss (*Lycopodiella cernua*), 7 ferns and 68 angiosperms.

The species they collected are very different from those found in the recent survey. Of the 76, only 6 species were recollected, *Excoecaria agallocha*, *Gynochthodes sublanceolata*, *Hoya verticillata* var. *verticillata*, *Ilex cymosa*, *Lygodium microphyllum* and *Oxyceros longiflora*. Many species previously collected are native climbers, epiphytes, lowland beach or mangrove forest species. Beach or coastal forest species include *Asplenium macrophyllum*, *Dischidia benghalensis*, *Garcinia hombroniana*, *Hoya verticillata* var. *verticillata* and *Oncosperma tigillarium*.

Most climbers were not recollected except for *Cayratia mollissima*, *Gynochthodes sublanceolata*, *Lygodium microphyllum* and *Oxyceros longiflora*. The change in the flora reflects the change in the environment. Tall trees would have had to be present to support the epiphytes and climbers. Probably these were logged during land clearance and *Oncosperma tigillarium* trunks were probably used for *kelong* poles. It is interesting to note that the largest family in the historical collections, the Orchidaceae with 27 species, has not a single species left today. Most orchids are epiphytes of lowland forest or mangrove trees. All except *Bulbophyllum membranaceum* and *Claderia mayeriana* are now extinct in Singapore and both the surviving species are considered vulnerable to extinction (Turner *et al.*, 1995). At present, only the weedy, terrestrial orchid, *Eulophia graminea* is present. All the epiphytic members of the Melastomataceae are also now extinct at Sg. Buloh and *Medinilla crassifolia* and *Plethiandra sessiliflora* are also extinct in Singapore.

Mangrove tree species are not among the earlier collections made by Ridley, Corporal or Goodenough, thus it is difficult to confirm if mangroves were present then. (*Excoecaria agallocha* is the closest to a mangrove tree species in their collections.) They were possibly discriminating collectors and ignored the mangrove trees, which were plentiful in other parts of the island. Indirect evidence of the existence of mangroves are the orchid species that were collected from the Sg. Buloh area and which are associated with mangroves. These include *Bulbophyllum concinnum*, *Bulbophyllum restrepia*, *Dendrobium spegidoglossum*, *Dendrobium spurium*, *Eria neglecta* and *Flickingeria xantholeuca*, all of which are now extinct in Singapore

(Turner *et al.*, 1995).

The name 'Sungei Buloh' is also very probably indicative of the presence of bamboo (Malay, *buloh*). No native bamboos were collected by past collectors or in this survey. (*Bambusa vulgaris*, a relic of cultivation, was the only bamboo collected in the recent survey.) As mentioned earlier, the past collectors may have ignored species which were common elsewhere on the island. Bamboos also tend to be sterile most of the time because of their generally infrequent flowering and collectors often collect only flowering and/or fruiting material.

Based on the recent survey of Singapore bamboos by Chua, Soong and Tan (1996) there are only four native bamboo species: *Gigantochloa ligulata* Gamble, *Schizostachyum gracile* (Munro) Holttum, *Schizostachyum latifolium* Gamble and *Soejatmia ridleyi* (Gamble) K.M. Wong. *Gigantochloa ligulata* is a recent new record for Singapore. It is unlikely to have grown at Sungei Buloh eighty years ago. *Soejatmia ridleyi* is an inland forest species, not associated with coastal areas and is currently found only at the Bukit Timah Nature Reserve, Singapore (Chua, Soong and Tan, 1996). Both *Schizostachyum gracile* and *Schizostachyum latifolium* may have grown at Sg. Buloh as both are common and grow at forest edges or riversides. Unfortunately, both are now extinct in Singapore.

Based on the conservation status ascribed by Turner *et al.* (1995) to species in Singapore, of the historical collections 30 species are now extinct, 3 endangered, 9 vulnerable, 27 rare, one common and two unknown. Three are endemic species and are found only in Singapore and Peninsular Malaysia: *Plethiandra sessiliflora*, *Rhopaloblaste singapurensis* and *Stachyphrynium griffithii*.

In terms of diversity, the current flora appears larger. This can be explained in two ways. Firstly, the survey was comprehensive and all species were collected, whereas the early collectors presumably concentrated only on the fertile material or what was of interest to them. Secondly, many species are weeds and are the result of disturbance caused by the prawn and fish farming and the construction of the park.

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Appendix 1. Recent collections from Sungei Buloh Nature Park. Conservation status: C = common; N = endangered; R = rare; V = vulnerable; A = naturalized exotic species (aliens); S = species escaped or persisting from cultivation.

Pteridophyta

Adiantaceae

A *Pityrogramma calomelanos* (L.) Link; K.S. Chua & Y.C. Wee CKS & WYC 506

Aspleniaceae

C *Asplenium nidus* L.; M.F. Choong VC 65; P.T.Chew, H.A. Kong & J.W.H. Yong SB 1053

Azollaceae

A *Azolla pinnata* R.Br. ssp. *asiatica* R.M.K.Saunders & K.Fowler; K.S. Chua, M. Mathews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3114

Blechniaceae

C *Stenochlaena palustris* (Burm.f.) Bedd.; K.S. Chua & Y.C. Wee CKS & WYC 513; M.F. Choong VC 12

Davalliaceae

C *Davallia denticulata* (Burm.f.) Mett.; I.M. Turner & M.F. Choong SB 1045

Dennstaedtiaceae

V *Pteridium esculentum* (G.Forst.) Cockayne; K.S. Chua & Y.C. Wee CKS & WYC 505; K.S. Chua, M. Mathews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3060

Gleicheniaceae

C *Dicranopteris linearis* (Burm.f.) Underw.; K.S. Chua & Y.C. Wee CKS & WYC 504

Oleandraceae

C *Nephrolepis auriculata* (L.) Trimen; Haji Samsuri bin Haji Ahmad SA.66; K.S. Chua & Y.C. Wee CKS & WYC 477; M.F. Choong VC 60

Parkeriaceae

C *Ceratopteris thalictroides* (L.) Brongn.; K.S. Chua, M. Mathews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3113

Polypodiaceae

C *Pyrossia lanceolata* (L.) Farwell; P.T.Chew, H.A. Kong & J.W.H. Yong SB 1056

C *Pyrossia piloselloides* (L.) M.G.Price; Haji Samsuri bin Haji Ahmad SA.56; I.M. Turner & M.F.Choong SB 1095; I.M. Turner & M.F. Choong SB 1037; I.M. Turner & M.F. Choong SB 1097

Pteridaceae

C *Acrostichum aureum* L.; P.T. Chew, H.A. Kong & J.W.H. Yong SB 1033; M.F. Choong VC 84; P.T. Chew, H.A. Kong & J.W.H. Yong SB 1033

C *Acrostichum speciosum* Willd.; K.S. Chua, M. Mathews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3000; P.T. Chew, H.A. Kong & J.W.H. Yong SB 13; P.T. Chew, H.A. Kong & J.W.H. Yong SB 13

C *Pteris vittata* L.; K.S. Chua, M. Mathews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3030

Schizaeaceae

C *Lygodium microphyllum* (Cav.) R.Br; I.M. Turner & M.F. Choong SB 1090

PINOPHYTA

Podocarpaceae

N *Podocarpus polystachyus* R.Br. ex Endl.; P.T. Chew, H.A.Kong & J.W.H. Yong SB 1016; Haji Samsuri bin Haji Ahmad SA.25

MAGNOLIOPHYTA

Acanthaceae

R *Acanthus ebracteatus* Vahl; Haji Samsuri bin Haji Ahmad SA.70; I.M. Turner & M.F. Choong SB 1086; P.T. Chew, H.A. Kong & J.W.H. Yong SB 1021; P.T. Chew, H.A. Kong & J.W.H. Yong SB 16

R *Acanthus ilicifolius* L.; Haji Samsuri bin Haji Ahmad SA.44; I.M. Turner & M.F. Choong SB 1085

R *Acanthus volubilis* Wall.; K.S Chua & Y.C. Wee 487; M.F.CHoong VC 79

A *Asystasia gangetica* (L.) T.Anderson ssp. *gangetica*; M.F. Choong VC 124; M.F. Choong VC 126

C *Asystasia gangetica* (L.) T.Anderson ssp. *micrantha* (Nees) Ensermu; Haji Samsuri bin Haji Ahmad SA 43; K.S. Chua & Y.C. Wee CKS & WYC 516; M.F. Choong VC 55; P.T. Chew, H.S. Kong & J.W.H Yong SB 1003

Aizoaceae

R *Sesuvium portulacastrum* (L.) L.; K.S. Chua, M. Mathews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3058

Amaranthaceae

A *Amaranthus caudatus* L.; P.T. Chew, H.A. Kong & J.W.H. Yong SB 1025

A *Amaranthus spinosus* L.; M.F. Choong SB 2

A *Celosia argentea* L.; M.F. Choong VC 118

Anacardiaceae

S *Mangifera indica* L.; M.F. Choong VC 138

Annonaceae

S *Annona muricata* L.; K.S. Chua & Y.C Wee 483; Haji Samsuri bin Haji Ahmad SA 54

Apocynaceae

C *Alstonia angustiloba* Miq.; K.S. Chua, M. Mathews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3011

A *Catharanthus roseus* (L.) G.Don; K.S. Chua, M. Mathews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3079

R *Cerbera* sp.; I.M. Turner & M.F. Choong SB 1035

Aquifoliaceae

R *Ilex cymosa* Blume; Haji Samsuri bin Haji Ahmad SA.71; K.S. Chua, M. Mathews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3061

Araceae

S *Caladium bicolor* (Aiton) Vent.; P.T. Chew, H.A. Kong & J.W.H. Yong SB 1064

C *Colocasia esculenta* (L.) Schott; M.F. Choong VC 110; M.F. Choong VC 116; M.F. Choong VC 135

S *Dieffenbachia seguine* (Jacq.) Schott in Wiener Z. Kunst; K.S. Chua, M. Mathews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3081

A *Pistia stratiotes* L.; K.S. Chua & Y.C. Wee CKS & WYC 572; K.S. Chua, M. Mathews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3078

Araliaceae

S *Schefflera actinophylla* (Endl.) Harms; I.M. Turner & M.F. Choong SB 1047

Asclepiadaceae

R *Dischidia major* (Vahl) Merr.; Haji Samsuri bin Haji Ahmad SA. 57; I.M. Turner & M.F. Choong SB 1096

C *Dischidia nummularia* R.Br.; K.S. Chua, M. Mathews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3050

V *Finlaysonia obovata* Wall.; K.S. Chua, M. Mathews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3004; M.F. Choong VC 123; P.T. Chew, H.A. Kong & J.W.H Yong SB 1055

R *Hoya verticillata* (Vahl) G.Don var. *verticillata*; K.S. Chua, M. Mathews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3086

V *Tylophora flexuosa* R.Br.; Haji Samsuri bin Haji Ahmad SA.30; P.T. Chew, H.A. Kong & J.W.H. Yong SB 1020; P.T. Chew, H.A. Kong & J.W.H. Yong SB 1068

Avicenniaceae

C *Avicennia alba* Blume; K.S. Chua & Y.C. Wee CKS & WYC 532; M.F. Choong VC 84; M.F. Choong PB 7; P.T. Chew, H.A. Hong & J.W.H. Yong SB 1013

R *Avicennia officinalis* L.; M.F. Choong PB 1; M.F. Choong VC 77; P.T. Chew, H.A.Kong & J.W.H. Yong SB 1031; P.T. Chew, H.A. Kong & J.W.H. Yong SB 1065

R *Avicennia rumphiana* Hallier f.; M.F. Choong VC 115; P.T. Chew, H.A. Kong & J.W.H Yong SB 14

Bignoniaceae

A *Spathodea campanulata* P.Beauv.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3006

S *Tabebuia rosea* (Bertol.) DC.; M.F. Choong VC 43; P.T. Chew, H.A. Kong & J.W.H. Yong SB 1062

Bombacaceae

S *Durio zibethinus* Murray; M.F. Choong VC 2; Haji Samsuri bin Haji Ahmad SA 69

Boraginaceae

A *Carmona retusa* (Vahl) Masam.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3013; I.M. Turner & M.F. Choong SB 1080

A *Cordia cylindristachya* (Ruiz & Pav.) Roem. & Schult; I.M. Turner & M.F. Choong SB 1081; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3014; M.F. Choong VC 25

C *Heliotropium indicum* L.; P.T. Chew, H.A. Kong & J.W.H. Yong SB 1050

Butomaceae

A *Limnocharis flava* (L.) Buch.; K.S. Chua & Y.C. Wee CKS & WYC 495

Caesalpiniaceae

R *Caesalpinia crista* L.; M.F. Choong PB 9; M.F. Choong VC 33

A *Calopogonium mucunoides* Desv.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3037

R *Intsia bijuga* (Colebr.) Kuntze; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3107

A *Senna alata* (L.) Roxb.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3080; P.T. Chew, H.A. Kong & J.W.H. Yong SB 10

A *Senna obtusifolia* (L.) Irwin & Barneby; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3069

Cannaceae

A *Canna indica* L.; Haji Samsuri bin Haji Ahmad SA. 20

Capparaceae

A *Cleome rutidosperma* DC.; K.S. Chua & Y.C. Wee CKS & WYC 523; M.F. Choong VC 3; M.F. Choong VC 54

Caricaceae

S *Carica papaya* L.; M.F. Choong VC 18; M.F. Choong VC 95

Celastraceae

N *Cassine viburnifolia* (Juss.) Ding Hou; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3054

Combretaceae

R *Lumnitzera littorea* (Jack) Voigt; M.F. Choong PB 4; P.T. Chew, H.A.Kong & J.W.H. Yong SB 1014; P.T. Chew, H.A. Kong & J.W.H. Yong SB 1114

R *Lumnitzera racemosa* Willd.; M.F. Choong VC 81; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3029

C *Terminalia catappa* L.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3067

Compositae

A *Ageratum conyzoides* L.; I.M. Turner & M.F. Choong SB 1066

R *Blumea balsamifera* (L.) DC.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3084

S *Complaya trilobata* (L.) Strother.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3025

A *Conyza bonariensis* (L.) Cronquist; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3085; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3105

A *Crassocephalum crepidioides* (Benth.) S.Moore; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3065

C *Eclipta prostrata* (L.) L.; P.T. Chew, H.A. Kong & J.W.H Yong SB 1008

A *Erechthites hieraciifolia* (L.) Raf. ex DC.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3016

R *Gynura procumbens* (Lour.) Merr.; P.T. Chew, H.A. Kong & J.W.H. Yong SB 1058

A *Mikania micrantha* Kunth; I.M. Turner & M.F. Choong SB 1092; M.F. Choong VC 7;M.F. Choong VC 10; M.F. Choong VC 15; M.F. Choong VC 58

R *Pluchea indica* (L.) Less.; P.T. Chew, H.A.Kong & J.W.H. Yong SB 1019; I.M. Turner & M.F. Choong SB 1083

A *Porophyllum ruderale* (Jacq.) Cass.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3044

A *Synedrella nodiflora* (L.) Gaertn.; K.S. Chua & Y.C. Wee CKS & WYC 490

C *Vernonia cinerea* (L.) Less.; I.M. Turner & M.F. Choong SB 1088

S *Vernonia elliptica* DC.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3087

C *Wollastonia biflora* (L.) DC.; Haji Samsuri bin Haji Ahmad SA. 37; K.S. Chua & Y.C. Wee CKS & WYC 578; M.F. Choong VC 22; M.F. Choong VC 57

Convolvulaceae

C *Ipomoea aquatica* Forsk.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3031

S *Ipomoea batatas* (L.) Lam.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3071; M.F. Choong VC 127; M.F. Choong VC 130

S *Ipomoea digitata* L.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3026

C *Ipomoea pes-caprae* (L.) R.Br. ssp *brasiliensis* (L.) Ooststr.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3042

S *Ipomoea quamoclit* L.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3036

S *Ipomoea triloba* L.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3028; P.T. Chew, H.A.Kong & J.W.H. Yong SB 1042

R *Merremia hederacea* (Burm.f.) Hallier f. forma *barbata* Ooststr.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3027

C *Xenostegia tridentata* (L.) D.F.Austin & Staples ssp. *tridentata*; I.M. Turner & M.F. Choong SB 1052

Cucurbitaceae

S *Coccinia grandis* (L.) Voight; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3072; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3073;K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3074

Cyperaceae

R *Cyperus compactus* Retz.; M.F. Choong SB 0001

C *Cyperus distans* L.f.; P.T. Chew, H.A. Kong & J.W.H. Yong SB 1049

C *Cyperus javanicus* Houtt.; P.T. Chew, H.A. Kong & J.W.H. Yong SB 1028; P.T. Chew, H.A.Kong & J.W.H. Yong SB 1070; K.S. Chua & Y.C. Wee CKS & WYC 478

R *Cyperus rotundus* L.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3093; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3094; K.S. Chua & Y.C. Wee CKS & WYC 534

R *Eleocharis ochrostachys* Steud.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3048

C *Fimbristylis acuminata* Vahl; K.S. Chua & Y.C. Wee CKS & WYC 494

R *Fimbristylis cymosa* R.Br.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3095

R *Fimbristylis ferruginea* (L.) Vahl; I.M. Turner & M.F. Choong SB 1074

C *Fimbristylis littoralis* Gaudich.; I.M.

Turner & M.F. Choong SB 1039

A *Kyllinga polyphylla* Willd. ex Kunth; K.S. Chua & Y.C. Wee CKS & WYC 485

R *Schoenoplectus mucronatus* (L.) Palla; K.S. Chua & Y.C. Wee CKS & WYC 480

C *Scleria levis* Retz.; K.S. Chua & Y.C. Wee CKS & WYC 514; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3106

Dilleniaceae

C *Dillenia suffructicosa* (Griff.) Mart.; K.S. Chua & Y.C. Wee CKS & WYC 526; Haji Samsuri bin Haji Ahmad SA.7; M.F. Choong VC 113

Elaeocarpaceae

A *Muntingia calabura* L.; K.S. Chua, M. Mathews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3068

Euphorbiaceae

C *Breynia reclinata* (Roxb.) Hook.f.; Haji Samsuri bin Haji Ahmad SA. 21; I.M. Turner & M.F.Choong SB 1077; P.T. Chew, H.A. Kong & J.W.H. Yong SB 1032

A *Euphorbia hirta* L.; K.S. Chua, M. Mathews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3075

R *Excoecaria agallocha* L.; Haji Samsuri bin Haji Ahmad SA.14; Haji Samsuri bin Haji Ahmad SA.53; I.M. Turner & M.F. Choong SB 1071; P.T. Chew, H.A. Hong & J.W.H. Yong SB 1061; P.T. Chew, H.A.Kong & J.W.H. Yong SB 1017

C *Mallotus paniculatus* (Lam.) M.A.; K.S. Chua, M. Mathews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3001

S *Manihot esculenta* Crantz; I.M. Turner & M.F. Choong SB 1044; M.F. Choong VC 13

A *Manihot glaziovii* M.A.; K.S. Chua & Y.C. Wee CKS & WYC 492/A

C *Phyllanthus debilis* Klein ex Willd.; K.S. Chua & Y.C. Wee CKS & WYC 497; K.S. Chua, M. Mathews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3111; M.F. Choong VC 98; P.T. Chew, H.A. Hong & J.W.H. Yong SB 1007; P.T. Chew, H.A. Hong & J.W.H. Yong SB 1023

C *Phyllanthus urinaria* L.; K.S. Chua, M. Mathews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3052

A *Ricinus communis* L.; K.S. Chua, M. Mathews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3012

C *Sapium discolor* (Champ. ex Benth.) M.A.; M.F. Choong VC 36

C *Sebastiania chamalaea* (L.) M.A.; K.S. Chua, M. Mathews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3017

Flagellariaceae

R *Flagellaria indica* L.; Haji Samsuri bin Haji Ahmad SA.16; Haji Samsuri bin Haji Ahmad SA. 59; I.M Turner & M.F. Choong SB 1101; K.S. Chua & Y.C. Wee CKS & WYC 484; M.F. Choong VC 121; M.F. Choong VC 133

Gramineae

A *Axonopus compressus* (Sw.) P.Beauv.; I.M. Turner & M.F. Choong SB 1078

S *Bambusa vulgaris* Schrad. ex Wendl.; M.F. Choong VC 131; M.F. Choong VC 21

A *Chloris barbata* Swartz; I.M. Turner & M.F. Choong SB 1075; M.F. Choong VC 101

C *Cynodon dactylon* (L.) Pers.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3023

C *Dactyloctenium aegyptium* (L.) Willd.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3024

C *Digitaria ciliaris* (Retz.) Koeler; K.S. Chua & Y.C. Wee CKS & WYC 482;

R *Digitaria longiflora* (Retz.) Pers.; I.M. Turner & M.F. Choong SB 1107

C *Echinochloa colona* (L.) Link; K.S. Chua & Y.C. Wee CKS & WYC 479; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3091

C *Eleusine indica* (L.) Gaertn.; K.S. Chua & Y.C. Wee CKS & WYC 527; M.F. Choong VC 132

C *Eriochloa procera* (Retz.) C.E.Hubb.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3022; P.T. Chew, H.A. Kong & J.W.H. Yong SB 1054; P.T. Chew, H.A. Kong & J.W.H. Yong SB 1054

C *Imperata cylindrica* (L.) P.Beauv.; P.T. Chew, H.A.Kong & J.W.H. Yong SB 1070; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3041; M.F. Choong VC 96

C *Ischaemum magnum* Rendle; K.S. Chua, M. Mathews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3019

C *Ischaemum muticum* L.; K.S. Chua & Y.C. Wee CKS & WYC 475; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3090

C *Leptochloa chinensis* (L.) Nees; K.S. Chua & Y.C. Wee CKS & WYC 474

A *Melinis repens* (Willd.) Zizka; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3018

C *Mnesithea glandulosa* (Trin.) Koning & Sosaf; I.M. Turner & M.F. Choong SB 1069

C *Ottochloa nodosa* (Kunth) Dandy; K.S. Chua & Y.C. Wee CKS & WYC 481

A *Panicum maximum* Jacq.; I.M. Turner & M.F. Choong SB 1099; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3056; M.F. Choong VC 100;M.F. Choong VC 134

A *Paspalum conjugatum* Berg.; I.M. Turner & M.F. Choong SB 1076; K.S. Chua & Y.C. Wee CKS & WYC 529; M.F. Choong VC 52

C *Paspalum vaginatum* Sw.; I.M. Turner & M.F. Choong SB1036; M.F. Choong VC 40

A *Pennisetum polystachyon* (L.) Schult.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3020

S *Saccharum officinarum* L.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3108

C *Sporobolus indicus* (L.) R.Br. var. *flaccidus* (Roem. & Schult.) Veldkamp; Haji Samsuri bin Haji Ahmad SA. 11; K.S. Chua, M. Mathews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3092

C *Sporobolus indicus* (L.) R.Br. var. *major* (Büse) Baaijens; K.S. Chua, M. Mathews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3021

A *Urochloa mutica* (Forsk.) T.-Q.Nguyen; I.M. Turner & M.F. Choong SB 1098

Guttiferae

R *Calophyllum inophyllum* L.; K.S. Chua & Y.C. Wee CKS & WYC 507

Labiatae

A *Hyptis brevipes* Poit.; P.T. Chew, H.A. Kong & J.W.H. Yong SB 1067

A *Hyptis capitata* Jacq.; K.S. Chua & Y.C. Wee CKS & WYC 511; M.F. Choong VC 6; M.F. Choong VC 14

R *Ocimum tenuiflorum* L.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3055

Lauraceae

C *Cinnamomum iners* Reinw. ex Blume; M.F. Choong VC 1

Lecythidaceae

R *Barringtonia asiatica* (L.) Kurz; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3088

Lemnaceae

C *Lemna perpusilla* Torrey; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3115

Liliaceae

S *Cordyline terminalis* Kunth; I.M. Turner & M.F. Choong SB 1043

Loganiaceae

C *Fagraea fragrans* Roxb.; I.M. Turner & M.F. Choong SB 1091; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3002

Loranthaceae

C *Dendrophthoe pentandra* (L.) Miq.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3082

C *Macrosolen cochinchinensis* (Lour.) Tiegh.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3010

Lythraceae

S *Cuphea hyssopifolia* Humb., Bonpl. & Kunth; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3101

C *Sonneratia alba* J.J. Smith; P.T. Chew, H.A.Kong & J.W.H. Yong SB 1048

Malpighiaceae

V *Tristellateia australasiae* A.Rich.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3083

Malvaceae

R *Abutilon indicum* (L.) Sweet; P.T. Chew, H.A. Hong & J.W.H. Yong SB 1024

C *Hibiscus tiliaceus* L.; M.F. Choong VC 38; M.F. Choong VC 50; M.F. Choong VC 82

C *Sida acuta* Burm.f.; Haji Samsuri bin Haji Ahmad SA.31; M.F. Choong VC 20; M.F. Choong VC 39; P.T. Chew, H.A. Hong & J.W.H. Yong SB 15; P.T. Chew, H.A. Hong & J.W.H. Yong SB 1063

C *Sida rhombifolia* L.; M.F. Choong VC 31; P.T. Chew, H.A.Kong & J.W.H. Yong SB 15; P.T. Chew, H.A.Kong & J.W.H. Yong SB 1015; P.T. Chew, H.A.Kong & J.W.H. Yong SB 1063

R *Thespesia populnea* (L.) Soland. ex Correa; I.M. Turner & M.F. Choong SB 1079; M.F. Choong VC 46; P.T. Chew, H.A. Hong & J.W.H. Yong SB 1011

C *Urena lobata* L.; Haji Samsuri bin Haji Ahmad SA.36; K.S Chua & Y.C. Wee 476; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3045; P.T. Chew, H.A. Hong & J.W.H. Yong SB 1018

Melastomataceae

A *Clidemia hirta* (L.) D.Don; I.M. Turner & M.F. Choong SB 1046; M.F. Choong VC 9

C *Melastoma malabathricum* L.; K.S. Chua & Y.C. Wee CKS & WYC 517; M.F. Choong VC 19

Meliaceae

S *Melia azedarach* L.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3099

R *Xylocarpus granatum* J.König; K.S. Chua & Y.C. Wee CKS & WYC 502; M.F. Choong PB. 8; M.F. Choong VC 75; M.F. Choong VC 87

Mimosaceae

A *Acacia auriculiformis* A.Cunn. ex Benth.; Haji Samsuri bin Haji Ahmad SA.50; K.S. Chua & Y.C. Wee CKS & WYC 489; M.F. Choong VC 68

A *Acacia mangium* Willd.; P.T. Chew, H.A. Kong & J.W.H Yong SB 1057

A *Adenanthera pavonina* L.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3100

R *Entada spiralis* Ridl.; K.S. Chua & Y.C. Wee CKS & WYC 531
A *Mimosa diplotricha* C.Wright ex Sauvalle; M.F. Choong VC 5; M.F. Choong VC 111
A *Mimosa pigra* L.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3047
A *Mimosa pudica* L.; I.M. Turner & M.F. Choong SB 1100; M.F. Choong VC 66
A *Neptunia plena* (L.) Benth.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3035; M.F. Choong VC 26
A *Paraserianthes falcataria* (L.) I.Nielsen; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3053

Moraceae

S *Artocarpus heterophyllus* Lam.; K.S. Chua & Y.C. Wee CKS & WYC 528
S *Artocarpus integer* (Thunb.) Merr.; M.F. Choong VC 8
R *Ficus apiocarpa* Miq.;K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3103
C *Ficus benjamina* L.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3005
C *Ficus fistulosa* Reinw. ex Blume; I.M. Turner & M.F. Choong SB 1041
C *Ficus grossularioides* Burm.f.; P.T. Chew, H.A. Hong & J.W.H. Yong SB 11
C *Ficus microcarpa* L.f.;M.F. Choong VC 108

Myricaceae

C *Myrica esculenta* Buch.-Ham.; I.M. Turner M.F. Choong SB 1034

Myrtaceae

S *Eugenia aquea* Burm.f.; Haji Samsuri bin Haji Ahmad SA 55
R *Eugenia polyantha* Wight; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3098
V *Eugenia rugosa* (Korth.) Merr.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3104
C *Eugenia spicata* Lam.; Haji Samsuri bin Haji Ahmad SA 58; K.S. Chua & Y.C. Wee CKS & WYC 509; P.T. Chew, H.A. Hong & J.W.H. Yong SB 1010
S *Psidium guajava* L.; M.F. Choong VC 16

Nepenthaceae

C *Nepenthes gracilis* Korth.; K.S. Chua & Y.C. Wee CKS & WYC 496

Onagraceae

C *Ludwigia hyssopifolia* (G.Don) Exell; K.S. Chua & Y.C. Wee CKS & WYC 492; P.T. Chew, H.A. Kong & J.W.H Yong SB 1026a

Opiliaceae

C *Champereia manillana* (Blume) Merr.; M.F. Choong VC 73

Orchidaceae

C *Eulophia graminea* Lindl.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3057

Palmae

V *Calamus erinaceus* (Becc.) Dransf.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3089
A *Cocos nucifera* L.; M.F. Choong VC 136
R *Nypa fruticans* Wurmb; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3008

Pandanaceae

S *Pandanus amaryllifolius* Roxb.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3076
C *Pandanus odoratissimus* L.f.; K.S. Chua & Y.C. Wee CKS & WYC 500

Papilionaceae

A *Aeschynomene americana* L.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3015

R *Aeschynomene indica* L.; I.M. Turner & M.F. Choong SB 1038

R *Alysicarpus vaginalis* (L.) DC.; M.F. Choong VC 28

A *Calopogonium mucunoides* Desv.; M.F. Choong VC 17; M.F. Choong VC 102

A *Centrosema pubescens* Benth.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3034; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3062

A *Clitoria ternatea* L.; M.F. Choong VC 34

A *Crotalaria pallida* Aiton; K.S. Chua & Y.C. Wee CKS & WYC 524

R *Dalbergia candenatensis* (Dennst.) Prain; K.S. Chua & Y.C. Wee CKS & WYC 508; M.F. Choong VC 122; P.T. Chew, H.A. Kong & J.W.H. Yong S.Buloh 17; P.T. Chew, H.A. Kong & J.W.H. Yong SB 17

C *Derris trifoliata* Lour.; Haji Samsuri bin Haji Ahmad SA.15; K.S. Chua & Y.C. Wee CKS & WYC 486; M.F. Choong VC 62; M.F. Choong VC 119; P.T. Chew, H.A. Hong & J.W.H. Yong SB 12; P.T. Chew, H.A. Hong & J.W.H. Yong SB 1004

C *Desmodium heterophyllum* (Willd.) DC.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3110; M.F. Choong VC 140

C *Desmodium triflorum* (L.) DC.; M.F. Choong VC 53; M.F. Choong VC 89

S *Erythrina variegata* L.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3009

A *Indigofera hirsuta* L.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3033; P.T. Chew, H.A. Hong & J.W.H. Yong SB 18

A *Macroptilium lathyroides* (L.) Urb.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3063

A *Sesbania cannabina* (Retz.) Poir.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3032; I.M. Turner & M.F. Choong SB 1103

A *Tephrosia noctiflora* Bojer ex Baker; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3046

Passifloraceae

A *Passiflora foetida* L.; Haji Samsuri bin Haji Ahmad SA.39; K.S. Chua & Y.C. Wee CKS & WYC 522; M.F. Choong VC 47

Polygaceae

A *Polygala paniculata* L.; M.F. Choong VC 56

Pontederiaceae

A *Eichhornia crassipes* (Mart.) Solms; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3096

Rhizophoraceae

R *Bruguiera cylindrica* (L.) Blume; Haji Samsuri bin Haji Ahmad SA.23; Haji Samsuri bin Haji Ahmad SA.52; K.S. Chua & Y.C. Wee CKS & WYC 535; M.F. Choong VC 30; P.T. Chew, H.A. Hong & J.W.H. Yong SB 1012

R *Bruguiera gymnorhiza* (L.) Say.; M.F.Choong PB 2; M.F. Choong VC 125; P.T. Chew, H.A. Hong & J.W.H. Yong SB 1059

R *Ceriops tagal* (Pers.) C.B.Rob.; I.M. Turner & M.F. Choong SB 1072; M.F. Choong VC 74; M.F. Choong VC 114

R *Rhizophora apiculata* Blume; K.S. Chua & Y.C. Wee CKS & WYC 499; M.F. Choong PB 11; M.F. Choong VC 86; M.F. Choong VC 129

R *Rhizophora mucronata* Lam.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3007; M.F. Choong PB 10

Rhizophora sp.; M.F. Choong VC 80

Rubiaceae

C *Gynochthodes sublanceolata* Miq.; Haji Samsuri bin Haji Ahmad SA. 62; I.M. Turner & M.F. Choong SB 1082; P.T. Chew, H.A.Kong & J.W.H. Yong SB 1002

R *Hedyotis dichotoma* Koen. ex Roth; I.M. Turner & M.F. Choong SB 1105

A *Morinda citrifolia* L.; Haji Samsuri bin Haji Ahmad SA.63; I.M. Turner & M.F. Choong SB 1094; K.S. Chua & Y.C. Wee CKS & WYC 537

R *Oxyceros longiflora* (Lam.) Yamazaki; Haji Samsuri bin Haji Ahmad SA.12

C *Paederia foetida* L.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3112; M.F. Choong VC 44; M.F. Choong VC 48; M.F. Choong VC 49; M.F. Choong VC 59; M.F. Choong VC 63; M.F. Choong VC 69; M.F. Choong VC 70; M.F. Choong VC 72; M.F. Choong VC 83; M.F. Choong VC 92;M.F. Choong VC 128

R *Psydrax* sp. 10 of Tree Flora of Malaya V.4; P.T. Chew, H.A. Kong & J.W. H. Yong SB 1009

R *Scyphiphora hydrophyllacea* Gaertn.f.; M.F. Choong VC 78

R *Timonius flavescens* (Jack) Baker; P.T. Chew, H.A. Kong & J.W.H. Yong SB 1009

R *Uncaria lanosa* Wall. var. *glabrata* (Blume) Ridsdale; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3059

Rutaceae

R *Melicope lunu-ankenda* (Gaertn.) T.G.Hartley; K.S Chua & Y.C. Wee 525; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3049

S *Murraya koenigii* (L.) Spreng.; I.M. Turner & M.F. Choong SB 1109

Sapindaceae

R *Allophylus cobbe* (L.) Raeusch.; K.S Chua & Y.C. Wee 491; M.F. Choong VC 24; P.T. Chew, H.A. Hong & J.W.H. Yong SB 1005

Sapotaceae

R *Pouteria obovata* (R.Br.) Baehni; P.T. Chew, H.A. Kong & J.W.H. Yong SB 1031

Scrophulariaceae

A *Scoparia dulcis* L.; K.S. Chua & Y.C. Wee CKS & WYC 521; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3077

Solanaceae

C *Physalis minima* L.; I.M. Turner & M.F. Choong SB 1027; K.S Chua & Y.C. Wee 501; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3043; M.F. Choong PB. 12; P.T. Chew, H.A. Hong & J.W.H. Yong SB 1027; P.T. Chew, H.A. Kong & J.W.H. Yong SB 1030; SB 1024

A *Solanum nigrum* L.; Haji Samsuri bin Haji Ahmad SA.18; K.S. Chua & Y.C. Wee CKS & WYC 493; P.T. Chew, H.A. Kong & J.W.H Yong SB 1026

A *Solanum torvum* Sw.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3064

Sonneratiaceae

C *Sonneratia alba* J.J.Smith; M.F. Choong PB 5; M.F. Choong PB 6; M.F. Choong VC 76

Tiliaceae

C *Triumfetta tomentosa* Bojer; I.M. Turner 93-102

Typhaceae

A *Typha angustifolia* L.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3070

Ulmaceae

C *Trema cannabina* Lour.; K.S. Chua & Y.C Wee 579; P.T. Chew, H.A. Kong & J.W.H. Yong SB 1029

C *Trema tomentosa* (Roxb.) Hara; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3051

Umbelliferae

C *Centella asiatica* (L.) Urb.; I.M Turner & M.F Choong SB 1089

Verbenaceae

R *Clerodendron inerme* (L.) Gaertn.; Haji Samsuri bin Haji Ahmad SA. 47; M.F. Choong VC 107; M.F. Choong VC 117; P.T. Chew, H.A.Kong & J.W.H. Yong SB 1001

A *Lantana camara* L; I.M. Turner & M.F. Choong SB 1073; M.F. Choong VC 11; M.F. Choong VC 23

R *Phyla nodiflora* (L.) Greene; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3040

R *Premna foetida* Reinw. ex Blume; M.F. Choong VC 35; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3066

C *Stachytarpheta indica* (L.) Vahl; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3039; M.F. Choong VC 51

A *Stachytarpheta jamaicensis* (L.) Vahl; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3038

C *Vitex pinnata* L.; K.S. Chua, M. Matthews, H.T.W. Tan, I.M. Turner & J.W.H. Yong SB 3003

Vitaceae

R *Cayratia mollissima* (Wall.) Gagnep.; M.F. Choong VC 37; M.F. Choong VC 42

C *Cissus hastata* (Miq.) Planch.; I.M. Turner & M.F. Choong SB 1084

Appendix 2. Historical collections from the Sungei Buloh area. Conservation status: C = common; N = endangered; R = rare; V = vulnerable; X = extinct; ? = information on herbarium sheet label could not be read.

Pteridophyta

Aspleniaceae

X *Asplenium macrophyllum* Sw.; J.S.Goodenough s.n. [1890]

Dennstaedtiaceae

X *Lindsaea borneensis* Hook.f. ex Baker; J.S.Goodenough & H.N.Ridley s.n. [9 Jan 1889]

X *Lindsaea parasitica* (Roxb. ex Griff.) Hieron.; J.S.Goodenough s.n. [30 Nov 1889]

Hymenophyllaceae

N *Cephalomanes obscurum* (Blume) K.Iwatsuki; J.S.Goodenough s.n. [30 Nov 1889]

Lycopodiaceae

C *Lycopodiella cernua* (L.) Pic.Serm.; J.S.Goodenough s.n. [30 Nov 1889]

Polypodiaceae

V *Microsorum punctatum* (L.) Copel.; J.S.Goodenough s.n. [30 Nov 1889]

Schizaeaceae

C *Lygodium microphyllum* (Cav.) R.Br.; J.S.Goodenough s.n. [30 Nov 1889]

C *Schizaea digitata* (L.) Sw.; J.S.Goodenough s.n. [30 Nov 1889]

MAGNOLIOPHYTA

Acanthaceae

R *Staurogyne griffithiana* (Nees) Kuntze; H.N.Ridley s.n. [1894]

Alangiaceae

R *Alangium griffithii* (C.B.Clarke) Harms; H.N.Ridley s.n. [1894]

Annonaceae

R *Desmos dasymachalus* (Blume) Safford; H.N.Ridley 6228 [1894]

R *Goniothalamus ridleyi* King; H.N.Ridley 6227 [1893]

Aquifoliaceae

R *Ilex cymosa* Blume; H.N.Ridley 5089 [1893]

Asclepiadaceae

V *Dischidia benghalensis* Colebr.; H.N.Ridley s.n. 9 Jan [1890]; H.N.Ridley 2729 [without date]

R *Hoya verticillata* (Vahl) G. Don var. *verticillata*; H.N.Ridley s.n. [18??]

Commelinaceae

R *Amischotolype gracilis* (Ridl.) I.M. Turner; H.N.Ridley s.n. [Oct 1899]

Connaraceae

R *Rourea fulgens Planch.;* J.S. Goodenough 2027a [30 Nov 1889]

Euphorbiaceae

R *Excoecaria agallocha* L.; H.N.Ridley 4425 [1892]

Flacourtiaceae

V *Ryparosa hullettii* King; Mat s.n. [April 1894]

Gesneriaceae

V *Cyrtandra pendula* Blume; H.N.Ridley s.n. [1894]

Guttiferae

N *Garcinia hombroniana* Pierre; Unknown collector 6197 [without date]

R *Cratoxylum cochinchinense* (Lour.) Blume; H.N.Ridley 6389 [189?]

Leguminosae

R *Archidendron contortum* (Mart.) I.C.Nielsen; H.N.Ridley 346? [1889]

Marantaceae

R *Stachyphrynium griffithii* (Baker) K.Schum.; H.N.Ridley s.n. [1894]

Melastomataceae

X *Medinilla crassifolia* (Reinw. ex Blume) Blume; H.N.Ridley s.n. [9 Jan 1890]; H.N.Ridley s.n. [9 Jul 1890]; H.N.Ridley s.n. [without date]

? *Medinilla* sp.; H.N.Ridley s.n. [without date]

R *Pachycentria maingayi* (C.B.Clarke) J.F.Maxwell; H.N.Ridley 1652 [without date]

X *Plethiandra sessiliflora* (Cogn.) Merr.; H.N.Ridley 2021 [9 Jan 1890]

Menispermaceae

R *Fibraurea tinctoria* Lour.; J.S.Goodenough s.n. [1893]

Myristicaceae

V *Myristica cinnamomea* King; H.N.Ridley 6266 [1894]

Myrsinaceae

V *Ardisia tuberculata* Wall. ex A.DC.;

Collector unknown s.n. [4 Aug ?]

Ochnaceae

X *Euthemis leucocarpa* Jack; L.C.Corporal 772 [18 Apr 1890]

Orchidaceae

X *Apostasia nuda* R.Br.; H.N.Ridley s.n. [Jan 1890]

X *Appendicula cornuta* Blume; J.S.Goodenough s.n. [30 Nov 1889]

X *Bulbophyllum concinnum* Hook.f.; H.N.Ridley s.n. [9 Jan 1890]; H.N.Ridley s.n. [1891]

V *Bulbophyllum membranaceum* Teijsm. & Binn.; H.N.Ridley s.n. [1891]

X *Bulbophyllum restrepia* Ridl.; J.S.Goodenough s.n. [1889]

V *Claderia viridiflora* Hook.f.; H.N.Ridley s.n. [1890]

X *Coelogyne mayeriana* Rchb.f.; J.S.Goodenough s.n. [4 Aug ?]; H.N.Ridley s.n. [1890]

X *Cymbidium bicolor* Lindl. ssp. *pubesccens* (Lindl.) Du Puy & P.J. Cribb; H.N.Ridley [1891]

X *Dendrobium concinnum* Miq.; L.C.Corporal s.n. [18 Apr 1890]

X *Dendrobium lobatum* (Blume) Miq.; H.N.Ridley s.n. [1890]

X *Dendrobium microglaphys* Rchb.f.; J.S.Goodenough s.n. [1890]

X *Dendrobium prostratum* Ridl.; H.N.Ridley s.n. [1890]

? *Dendrobium* sp.; H.N.Ridley s.n. [9 Jan 1890]

X *Dendrobium spegidoglossum* Rchb.f.; J.S.Goodenough s.n. [30 Nov 1889]

X *Dendrobium spurium* (Blume) J.J.Sm.; J.S.Goodenough s.n. [1892]

X *Dendrobium villosulum* Lindl.; J.S.Goodenough 369? [29 Jan 1889]

X *Eria floribunda* Lindl.; H.N.Ridley 1634 [9 Jan 1890]

X *Eria neglecta* Ridl.; H.N.Ridley s.n. [1890]; H.N.Ridley s.n. [1891]

X *Eria nutans* Lindl.; H.N.Ridley s.n. [1890]

X *Eria pannea* Lindl.; J.S.Goodenough s.n. [30 Nov 1889]

X *Eria pulchella* Lindl.; H.N.Ridley s.n. [1890]

X *Eria tenuiflora* Ridl.; J.S.Goodenough s.n. [1892]

X *Flickingeria xantholeuca* (Rchb.f.) A.D.Hawkes; H.N.Ridley s.n. [4 Aug 1890]

X *Galeola nudifolia* Lour.; H.N.Ridley s.n. [9 Jan 1890]

X *Schoenorchis micrantha* Blume; H.N.Ridley 374 [30 Nov 1889]

X *Thelasis carinata* Blume; H.N.Ridley s.n. [9 Jan 1890]

X *Trichotosia velutina* (Lindl.) Lodd. ex Kraenzl.; H.N.Ridley [9 Jan 1890]

Palmae

R *Oncosperma tigillarium* (Jack) Ridl.; J.S.Goodenough 1663 [29 Nov 1889]; J.S.Goodenough 3145 [1890]; J.S.Goodenough 3509 [29 Nov 1889]

R *Rhopaloblaste singaporensis* (Becc.) Hook.f.; H.N.Ridley 2135 [May 1890]

Pandanaceae

V *Freycinetia angustifolia* Blume; J.S.Goodenough s.n. [30 Nov 1889]

Rubiaceae

N *Diplospora malaccensis* Hook.f.; H.N.Ridley s.n. [1894]

R *Gardenia tubifera* Wall. var. *subcarinata* Corner; H.N.Ridley s.n. [1891]

C *Gynochthodes sublanceolata* Miq.; J.S.Goodenough s.n. [4 Aug 1890]

R *Hedyotis pinifolia* Wall. ex G.Don; Unknown collector 8925 [1897]

R *Oxyceros longiflora* (Lam.) T.Yamaz.; J.S.Goodenough 2415 [16 Sep 1891]

R *Prismatomeris glabra* (Korth.) Valeton; H.N.Ridley s.n. [1894]

R *Psychotria penangiana* Hook.f.; Corporal 2870 [18 Apr 1890]

R *Timonius flavescens* (Jack) Baker; H.N.Ridley s.n. [without date]
R *Urophyllum glabrum* Wall.; H.N.Ridley s.n. [12 Jan 1890]

Sterculiaceae
R *Pterospermum javanicum* Jungh.: H.N.Ridley 6181 [1894]

Styraceae
V *Styrax benzoin* Dryand. var. *benzoin;* H.N.Ridley s.n. [1894]

Vitaceae
R *Cayratia mollissima* (Wall.) Gagnep.: Corporal s.n. [8 Apr 1890]

Zingiberaceae
R *Hornstedtia leonurus* (J.König) Retz.; H.N.Ridley s.n. [1911]
R *Hornstedtia scyphifera* (J.König) Steud. var. *scyphifera*; H.N.Ridley s.n. [1894]

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Baccaurea scortechinii distinct from *B. parviflora* (Euphorbiaceae)

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Abstract

Baccaurea scortechinii Hook. *f.* is a species distinct from *B. parviflora* (Müll. Arg.) Müll. Arg. recognised by a combination of the following characters: greater number of pairs of veins, proportionately wider leaf, shorter male and female inflorescences, position of the female inflorescence on the upper part of the trunk or on the branches, short pedicel of male flowers, longer sepals of the female flower, which are hoary outside, the rosy pink, obovoid ridged fruit (often with a wrinkled surface), which has a thick pericarp and up to six seeds.

Introduction

Over reliance on herbarium material as opposed to field observations can sometimes lead to erroneous results. A case in point is the synonomising of *Baccaurea scortechinii* with *B. parviflora* (Airy Shaw, 1972).

In the field, these two species are totally distinct based on the position of the infructescences, the colour and shape of the fruits and whether the fruits are ridged or not. Corner (1952) described *B. scortechinii* as the 'Chinese Lantern Tree' because 'the fruiting trees look as if they were hung with little Chinese lanterns'. He described the fruits as being rose-pink and six-ridged and hanging from the branches on strings. The infructescences are also produced on the trunk but never from the base. In contrast, the fruits of *B. parviflora* are smooth, purple-brown and are produced on strings at the base of the trunk and trail in profusion on the ground. In the field, these two species are certainly distinct!

The inability to distinguish between the two *Baccaurea* species with elongate fruits and terminalia branching may in part be due to the poor choice of characters in keys for identifying them. Thus, Pax and Hoffman (1922) used the degree of pubescence of the young twigs, a character that cannot be used for specimens with older twigs, which are uniformly glabrous in both species. Ridley (1924) used leaf shape, which, while it can be used for the extremes of variation, also shows considerable overlap. He

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contributed to the confusion by adding a note to his description of *B. scortechinii* stating that 'Hooker says racemes from the branches, though in the specimens I have seen at Kew they all appear to have been from the stem as in *B. parviflora*, but *B. parviflora* does sometimes have racemes from the branches' (though this fact is not mentioned in Ridley's description of *B. parviflora*). Whitmore (1973) was of the opinion that those species with terminalia branching 'are extremely difficult to distinguish without fruits because the leaves are similar, and variable, within each species'.

Based on a study of herbarium specimens, Airy Shaw (1972) reduced *B. scortechinii* to synonomy with *B. parviflora* without giving a reason for his decision. Whitmore (1973) followed Shaw in regarding it as a synonym of *B. parviflora* but as Corner (1988) commented 'there seems to be some mistake'.

Baccaurea scortechinii was first described by Hooker f. based on a single specimen (*Scortechini s.n.*, Perak) and it has remained poorly known. The fruit and the position of the inflorescence were not known to Hooker but the character of number of vein pairs that he gave is useful in distinguishing these two species (Table 1). Now that more specimens are available, it is possible to reassess the characters that are used to separate the two species.

Fruiting specimens of *B. parviflora* and *B. scortechinii* are readily identified based on whether the fruits are ridged or not, their colour and shape, and the position and length of the infructescence (Table 1). Specimens with female flowers can be identified by flower size, indumentum of the sepals and whether the ovary is ridged or not (but in fact have rarely been collected) and those with male flowers by the length of the pedicel.

Sterile material can be identified by the number of pairs of veins and also by the *gestalt* of the terminalia branching. In *B. parviflora* the distal two or three tiers of caulomeres frequently have slender twigs of equal thickness suggesting that they were produced by the same growth flush. In contrast, it appears that usually only a single tier of caulomeres is produced at a time in *B. scortechinii* as the distal twig is much more slender than the adjacent proximal one. In the field, *B. scortechinii* has a conspicuously narrow crown, perhaps the result of this less profuse mode of growth. The phenology of these growth flushes is not known.

Flowering is, however, seasonal occurring in the two main flowering seasons for trees (Kiew, 1986). Corner (1952) noted that *B. parviflora* flowers gregariously after a dry spell. Most male flowering specimens have been collected between January and April with a peak in February to March with a few in June-July and October (specimens with female flowers are scarce but have been collected in February to April and in September) and fruiting specimens from May to September. *B. scortechinii* fruits

between March and April and again in June-July and September, but there is insufficent flowering material to assess its flowering seasons.

Baccaurea parviflora is widespread from Burma to Borneo (where it has rarely been collected). In Peninsular Malaysia, it has been collected from all states and is common in the lowlands up to 1300 m altitude. It is most frequently collected from hill slopes and ridge tops. In contrast, *B. scortechinii* has been more frequently collected from forest beside streams and rivers. *B. scortechinii* is endemic to Peninsular Malaysia and is more common in Kelantan, Trengganu and Pahang.

Table 1. *Baccaurea parviflora* and *B. scortechinii* compared

Character	*B. parviflora*	*B. scortechinii*
bark[1]	finely ridged	not ridged
bark colour[1]	brownish grey	pale fawn
lamina length (cm)	8.5–15.5	13–18
lamina width (cm)	3–5	5–9.5
lamina l:w ratio	2.8–-3.1	1.9–2.6
no. vein pairs	(4–) 5 (–6)	(6–) 7 (–9)
male raceme length (cm)	10–15	3.5–8
male pedicel length (mm)	3–4	1–1.5
female raceme length (cm)	15–30	5.5–12
female raceme position	base of truck	trunk and branches
male & female sepal shape	ovate	oblong
female sepal length (mm)	2.5–3.5	8–9
female sepal indumentum (outer surface)	glabrous	hoary
ovary shape	cylindrical	ovoid
ripe fruit colour	purple brown	rosy pink
fruit shape	fusiform	obovoid
	not ridged	6-ridged
fruit apex	narrowed	rounded
pericarp thickness (mm)	1.5–2.0	0.5–1.1
no. seeds per fruit	1–3	1–6

[1]from Corner (1988). No details are available on labels of herbarium specimens to verify this.

Baccaurea parviflora

Baccaurea parviflora (Müll. Arg.) Müll. Arg. in DC Prodromus **XV**(2) (1866) 462.
Figure 1.
Type: *Wallich 7759B* Tavoy, India. (K holo)
Hook. *f.* Fl. Brit. India. **5** (1887) 368; Pax & Hoff. Pflanzenreich. iv **147 XV** (1922) 59; Ridley Fl. Mal. Pen. **3** (1924) 243, Fig. 152; Corner Wayside Trees. (1952) 241, Fig. 71.
Pierardia parviflora Müll. Arg. in Linnaea **32** (1863) 82.

Small tree to 15 m tall and 7.5–10 cm dbh., flowering at 2 m, with terminalia branching with leaves clustered at the tips of the twigs, twigs slender with long internodes and pilose, becoming glabrous with age. Bark brownish-grey, rather closely and finely ridged. Stipules lanceolate, pubescent outside. Young leaves pinkish. Petiole 0.75–3 cm long, grooved above. Lamina oblanceolate, (8.5–) 12 (–15) cm long and (3–) 4 (–5) cm wide; apex caudate, base strongly acute, margin entire, apex caudate, glabrous above and beneath; in dried state thinly coriaceous, smooth (not puckering); veins (4–) 5 (–6) pairs prominent beneath, tertiary veins inconspicuous.

In male trees raceme cauliflorous in more or less upright tufts on burrs on trunk about 3 m above the ground, sometimes on branches, 10–15 cm long, hairy. Bracts minute, broadly ovate, 0.2–0.3 mm long, densely tomentose. Flower fragrant with a sharp lemon scent. Pedicel 3–4 mm long. Sepals 4–5, ovate, 1.0–1.5 mm long and 0.5–1 mm wide, yellowish green (rarely reddish brown). Stamens (3–) 6, filaments 0.1–0.2 mm, anthers subglobose, 0.2 mm long, yellow. Pistillode large.

In female trees, raceme cauliflorous, numerous and always at the base of the trunk, (15–) 23 (–30) cm long. Peduncle reddish. Bracts cordate, 0.1–0.2 mm long, tomentose. Pedicel 3-4 mm long. Sepals 5, spathulate, 2.5–3.5 mm long and 0.5–1 mm wide, deep red and almost glabrous outside, white and finely pilose inside. Ovary cylindric, 3-loculate, 1.5–2 mm long and 1–1.5 mm wide, dark red, finely pilose. Style 0.5–1 mm long. Stigma 3, each bifurcating and recurved, dark red.

Berry fusiform, stigma persistent, 1.25–2.75 cm long and 11.5 cm wide, dark red turning purple brown, sour. Pericarp fleshy, smooth, indehiscent, 13–20 mm thick. Seeds 1–3, oval, thin, 9–12 mm long, 5–6 mm wide, aril fleshy, magenta, testa brown.

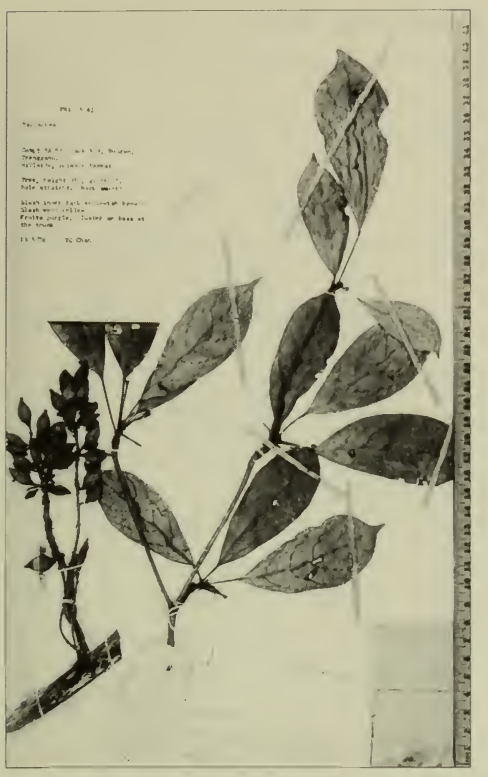

Figure 1. *Baccaurea parviflora*

Figure 2. *Baccaurea scortechinii*

Anatomy of Ovary and Fruit

T.S. Ovary: (Fig. 3A, C)
Round with 3 locules, ovary wall (0.40–) 0.48 (0.55) mm thick, ovules 1 or 2 per locule. Vascular bundles 3, positioned midway in the ovary wall opposite the locules with 2-4 minor bundles in between.

Epidermis thin, cells isodiametric (10–) 15 (–20) µm wide. Trichomes sparse, unicellular (0.15–) 0.27 (–0.3) mm long. Cortex (350–) 430 (–500) µm thick, cells of inner layer (35–) 40 (–45) µm thick. Xylem vessels small, (5–) 8 (–10) µm diameter.

T.S. Fruit: (Fig. 4A, C).

Round with 3 locules, 1–3 seeds per fruit. Pericarp fleshy (1.5–) 1.8 (–2.0) mm thick. Arrangement of vascular bundle as for ovary.

Exocarp thin, single layered, cells (50–) 53 (–55) µm long and (20–) 23 (–25) µm wide, becoming almost glabrous. Mesocarp (1.0–) 1.3 (–1.5) mm thick; outer and central region with scattered large cells with thickened

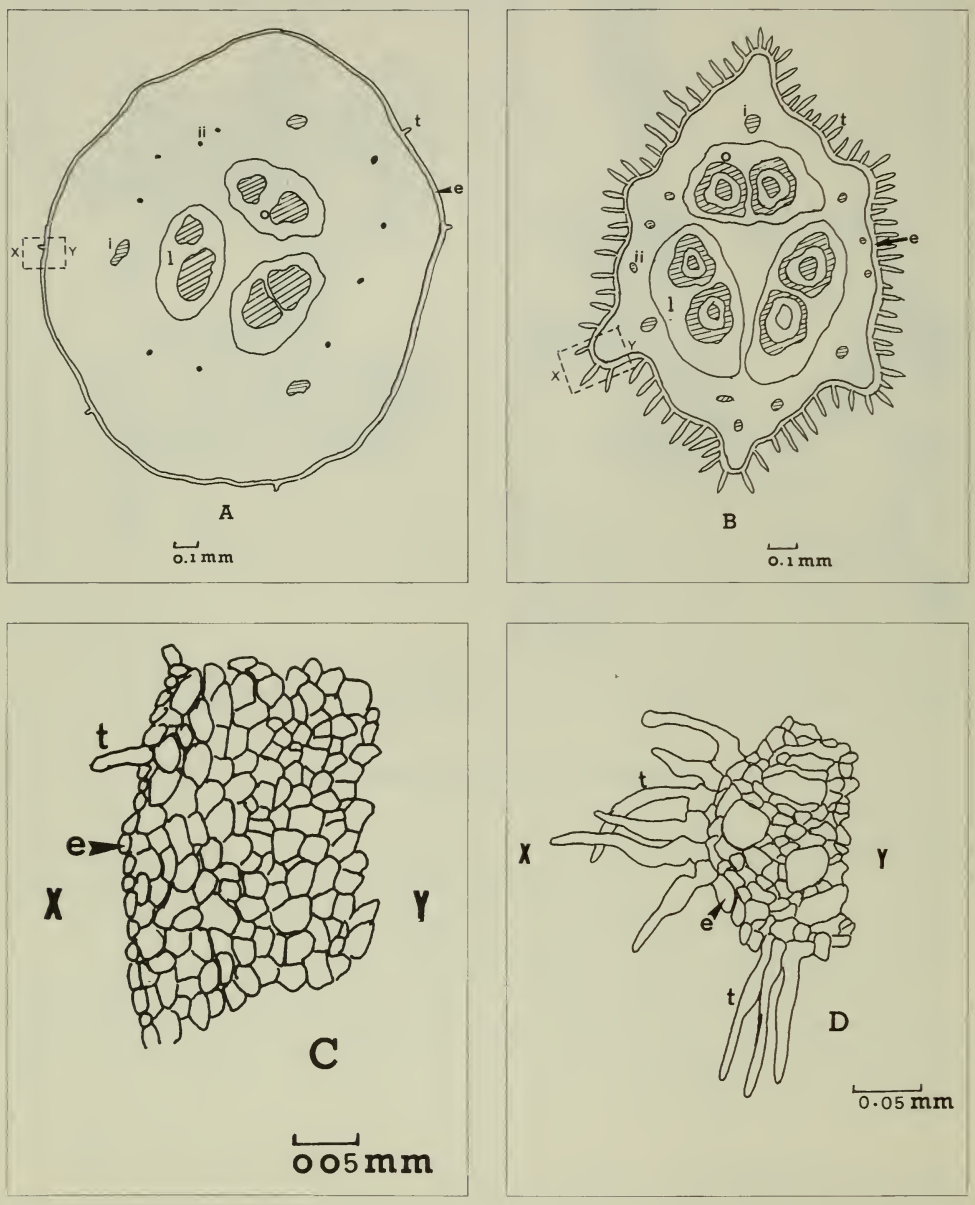

Figure 3. T.S. ovary: A *Baccaurea parviflora*, B *B. scortechinii.*
Outer layers of ovary: C *B. parviflora*, D *B. scortechinii.*
i major vascular bundle, ii minor vascular bundle, o ovule, t trichomes, e epidermis, l locule.

cellulose walls, cells in the central region larger and more numerous. Endocarp with several layers of brachysclereids.

Distribution: Burma, Thailand, Peninsular Malaysia (all states), Philippines and Borneo.

Habitat: Lowland forest, frequently on hill slopes and ridges up to 1300 m.

Local Name: Setambun (Malay).

Notes: Earlier descriptions cited the male flowers as having up to eight stamens but this is an error based on the inclusion of specimen *King's Coll. 3321* (K) with 6-8 stamens in *B. parviflora* when it does not belong to this species as its inflorescneces are produced on the twigs.

Ridley (1924) recorded that the flowers are 'scented like cowslips' and Corner (1952) that when it flowers gregariously it scented the forest. The male flowers are usually yellow but Ridley observed trees with red flowers at Semangkok and, close by at Fraser's Hill, crimson-flowered trees are seen though they are less common than the yellow-flowered ones (Kiew, 1998).

Burkill (1966) reports that the Semai in Perak use dibbling sticks of *B. parviflora* because 'they suppose, its habit of fruiting close to the ground may ensure the hill-rice having a short straw, inhibiting it from being lanky in growth'.

There is another (as yet unnamed) taxon with terminalia branching and elongate fruits collected from Trengganu, which shares characters with both *B. parviflora* and *B. scortechinii,* i.e. its fruits are ridged like *B. scortechinii* but are produced on long inflorescences at the base of the tree as in *B. parviflora.* It is, however, distinct from these two species in its extremely long petioles (c. 5 cm long). The petioles of both *B. parviflora* and *B. scortechinii* are variable in length depending on the leaf's position within the tuft, the shortest being about 0.75 cm and the longest 3 cm long.

Baccaurea scortechinii

Baccaurea scortechinii Hook. *f.* Fl. Brit. India. **5** (1887) 368.
Figure 2.
Type: *Scortechini s.n.* Perak (K, Kew no. H/0980/88 71 - lectotype, here chosen; L, SING iso)
Pax & Hoff. Pflanzenreich. iv **147 XV** (1922) 56; Ridley Fl. Mal. Pen. 3 (1924) 244; Corner Wayside Trees. (1952) 242.

Small tree to 10 m with 5–10 cm dbh, flowering at 3 m; with terminalia branching with clusters of leaves at the tips of the twigs, twigs minutely hirsute becoming glabrous with age. Bark pale fawn, slightly flakey, not ridged. Stipules subulate. Petiole 0.75–3 cm long, grooved above. Lamina oblanceolate to subrhomboid, (13–) 14 (–18) cm long and (5–) 6 (–9.5) cm wide; apex caudate, base strongly acute, margin entire, glabrous above and beneath; in the dried state chartaceous and puckering along the tertiary veins; midrib usually minutely pilose beneath, veins (6–) 7 (–9) pairs, prominent beneath, tertiary veins conspicuous above and beneath.

In male trees raceme cauliflorous about 3 m from the ground, 3.5–8 cm long. Bracts minute, broadly ovate, c. 0.1 mm long, tomentose. Flowers white. Pedicel 1–1.5 mm long. Sepals 4–6, oblong, 1–1.5 mm long and 0.5–1 mm wide. Stamens 4–5, filament c. 0.1 mm long, anthers subglobose, 0.1 mm long. Pistillode large.

In female trees, raceme slender, pendant, cauliflorous or less usually ramiflorous but never from the base of trunk, 6.5–12 cm long. Bracts minute, cordate, 0.1–-0.2 mm long and 0.1–0.2 mm wide, tomentose. Pedicel 2–2.5 mm long. Sepals 5, pale yellow, oblong, 8–9 mm long and 1–2 mm wide, margin inrolled, densely tomentose inside and out. Ovary ovoid, 6-ridged and 3-loculate, 2– mm long and 1–2 mm wide, red, densely pilose. Style 0.5–1 mm long. Stigma 3, each bifurcating and recurved.

Berry obovoid, stigma persistent, 6-ridged often finely wrinkled between the ridges, (1.5–) 2.2 (–2.5) cm long and 1.2–1.5 cm wide, rosy pink, sour. Pericarp fleshy, indehiscent, (5–) 8 (–11) mm thick. Seeds 1–6, oblong, thin, 3–4 mm long and 1–2 mm wide, aril fleshy, purple, testa brown.

Anatomy of the Ovary and Fruit

T.S. Ovary (Fig. 3B, D).

Six-ridged with 3 locules, ovary wall (0.1–) 0.18 (–0.3) mm thick. Ovules 1–2 per locule. Vascular bundles 3, positioned midway in the ovary wall opposite the locules with 3 minor bundles in between.

Epidermal cells narrow, isodiametric (10–) 15 (–20) μm wide. Trichomes abundant, unicellular, (0.11–) 0.13 (-0.16) mm long originating from the epidermal layer. Cortex with cells (10–) 15 (–20) μm wide, decreasing in size towards the exterior. Xylem vessels small, (5–) 8 (–10) μm diameter.

T.S. Fruit (Fig. 4B, D).

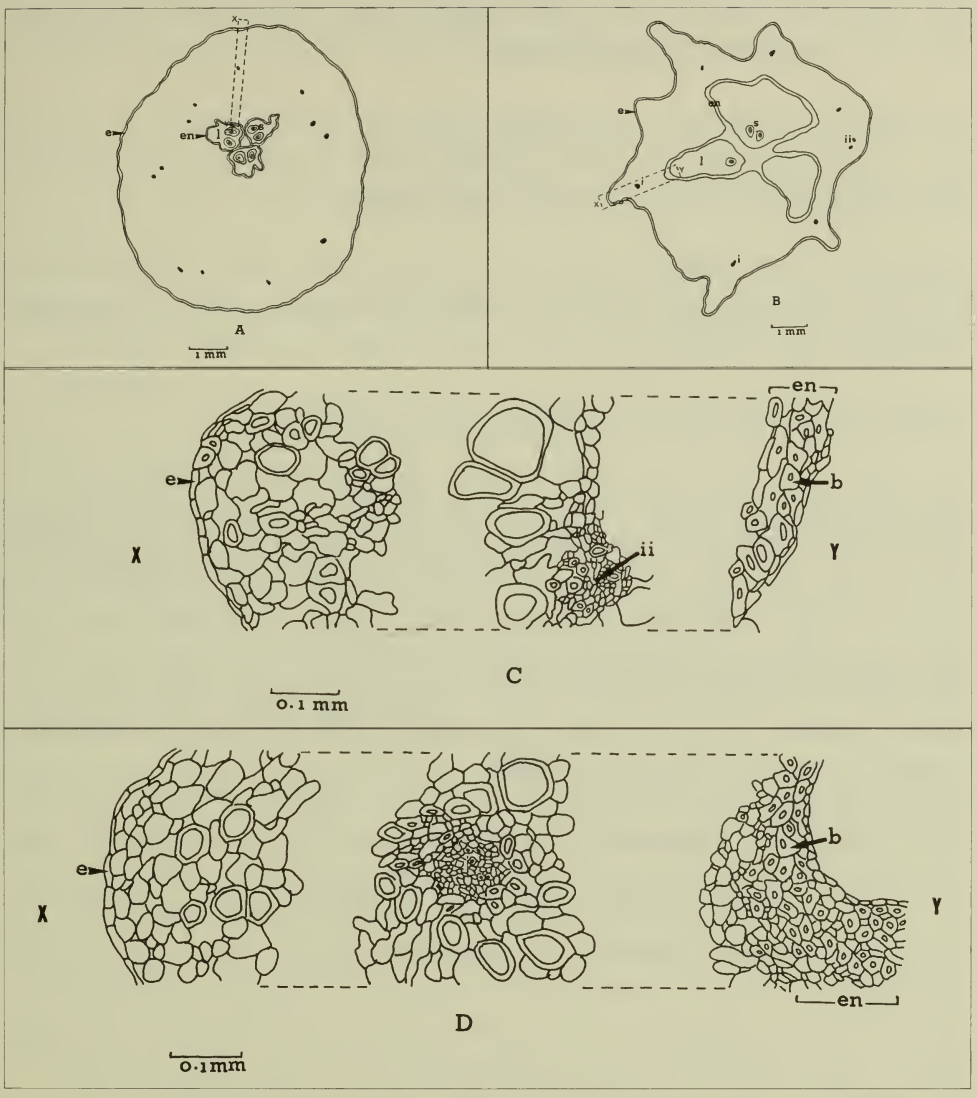

Figure 4. T.S. fruit: A *Baccaurea parviflora*, B *B. scortechinii.*
T.S. pericarp: C *B. parviflora*, D *B. scortechinii.*
i major vascular bundle, ii minor vascular bundle, b brachysclereids, e epidermis, en endocarp, s seed.

Six-ridged with 3 locules, 1–6 seeds per fruit. Pericarp fleshy (0.5–) 0.8 (–1.1) mm thick. Arrangement of vascular bundles as for ovary.

Exocarp thin, single layered, cells narrow (10–) 11 (–12) μm long and (15–) 18 (–20) μm wide, becoming almost glabrous. Mesocarp (0.3–) 0.4 (0.5) mm thick; outer and central region as for *B. parviflora.* Endocarp with several layers of brachysclereids.

Distribution: Endemic to Peninsular Malaysia, most common in central and northern regions and from Gunung Panti, Johore (not yet collected from Perlis, Kedah, Negri Sembilan and Malacca).

Habitat: Lowland primary forest up to 200 m a.s.l., often by streams and rivers, once from a wang in limestone *(RK 3001)* and the base of a limestone cliff *(Henderson 25005).*

Local names: asam tamun, setambun antan (Malay).

Specimens examined: KELANTAN: Batu Boh *Kiew & Anthonysamy RK 3001* (UPM), Kampung Parit *Hanif & Nur SFN 10241* (SING), Kuala Betis *Ng FRI 5532* (K, KEP, SING), *Whitmore FRI 5532* (L), Sungai Lebir *Henderson 29535* (SING), *Stone & Mahmud 12427* (KEP), *Whitmore FRI 4311* (K, KEP, L, SING). TRENGGANU: Sekayu *Loy FRI 13515* (K, KEP, L), Ulu Besut *Cockburn FRI 8251* (KEP), Ulu Brang *Moysey & Kiah SFN 33866* (SING), Ulu Sungai Trengan *Cockburn FRI 10581* (K, KEP, L, SING), *Wong & Khairuddin FRI 32616* (L, SING). PAHANG: Bukit Chintamani *Henderson 25005* (SING), Jeruntut *Holttum 24747* (SING), Kuala Lompat *Whitmore FRI 34477* (KEP, L, SING), *Saw FRI 36300* (KEP, L), Kuala Tembeling *Ridley s.n.* (SING), Panching *Ogata 10473* (KEP), Raub *Kalong 20247* (KEP), Sungai Kenyam *Whitmore FRI 20160* (KEP), Taman Negara (Merapoh) *Soepadmo & Suhaimi S260* (L), (Sungai Tahan) *Mohd Shah & Ahmad Shukor MS2658* (L), *Wyatt-Smith KEP 71960* (K, L), Ulu Tembeling *Henderson 21785* (SING), *22004* (SING). PERAK: no locality *Scortechinii s.n.* (fruits, L, SING), (male flowers, SING). SELANGOR: Kuala Pansom *Gadoh KL 1324* (SING). JOHOR: Gunung Panti *Corner 29408* (SING), *Kochummen KEP 99204* (KEP).

Notes: There are three sheets of Scortechini's collections at K. The one selected as the lectotype is his unnumbered collection, which has mature fruits and female flowers. Of the other two sheets, *Scortechini 1992* has male flowers and *Scortechinii 2002* has female flowers but no fruits. None of Scortechini's labels gives any information about exact locality, habitat or position of the inflorescences.

Acknowledgements

We are indebted to S. Anthonysamy for assistance in the field and to the curators of the herbaria of K, KEP, L and SING for permission to examine specimens in their care and to Raoule Hagen for stimulating discussions on the two species and for advice on extra-Malayan species.

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New Records of Plant Species from Singapore

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Abstract

Most notable among the 28 new records of flowering plant species from Singapore are the first record of *Mukia maderaspatana* (Cucurbitaceae) for both Singapore and Peninsular Malaysia, the first record for several genera - *Chonemorpha*, *Ichnocarpus* and *Kibatalia* (Apocynaceae), *Gymnanthera* (Asclepiadaceae) and *Scaphochlamys* (Zingiberaceae) and the two dipterocarps, *Dipterocarpus elongatus* and *Shorea ochrophloia.*

Introduction

In 1994, Turner reported the flora of the vascular plants of Singapore to number 2277 species in 868 genera and 158 families. New records (those not listed by Turner, 1993) continue to be added and 18 of these are already published (Turner *et al.* 1994, 1997).

Here we list a further 28 species. Of these, a few are previously overlooked species, such as *Hedyotis verticillata*, *Ichnocarpus serpyllifolius*, *Piper macropiper* and *Xanthophyllum amoenum* that were in fact collected many years ago. Many were recorded when plots were set up in the Central Catchment Nature Reserve (which includes the MacRitchie area and the Nee Soon Freshwater Swamp) as part of a survey commissioned by the National Parks Board, which was carried out in 1992 and 1993 (Wong *et al.*, 1994). However, even a forest as well known as the Bukit Timah Nature Reserve continues to turn up new records. Perhaps more surprising is that some of these are large canopy trees, such as *Shorea ochrophloia*, that are visible from commonly walked trails (Lum and Sharp, 1996).

All specimens cited here are lodged at SING.

New Records

Apocynaceae *Alstonia macrophylla* Wall. *ex* G. Don
Singapore (without locality) *N. Cantley s.n.* — 1880s; Pulau Sentosa *Heaslett s.n.* — 29 Jan 1973, Mount Faber *Sao Kyi Win 24/AmI* — 16 June 1983.

Also observed in Pierce Reservoir area, Central Catchment Nature Reserve.
Distribution: Indo-China and Thailand south to Sulawesi.

Apocynaceae *Alstonia pneumatophora* Back. *ex* L.G. den Berger
MacRitchie area, Central Catchment Nature Reserve *Wong, Ali & Chew 15* — Aug 1994.
Also observed from Nee Soon Stream near Lorong Banir and a fine tree with a 3.4 m girth grows in the Zoological Garden, Mandai.
Distribution: Sumatra, Peninsular Malaysia, Singapore, Riouw, Borneo and Sulawesi.

Apocynaceae *Chonemorpha fragrans* (Moon) Alston
Nee Soon Firing Ranges, Central Catchment Nature Reserve. *Joseph Lai & Ali Ibrahim LJ 102* — 5 Nov 1996.
Distribution: India, Sri Lanka, Myanmar, Peninsular Malaysia, Singapore and Java.

Apocynaceae *Ichnocarpus serpyllifolius* (Blume) P.I. Forster
This common, but overlooked, species was first identified by David Middleton and Ali Ibrahim. This enabled a specimen, unnumbered and undated (although the label indicated that it had been collected in the 1920s) that had long lain in the herbarium unidentified even to its family (*accession number 082726*) to be identified. The collector is recorded as Barnay Batto and the notes on the label read: "The leaf is used for those who got smallpox is make into powder and with little safron is mixed with run over the body."
Recent collections include:
Bukit Timah Nature Reserve *Ali Ibrahim AI 212* — 14 September 1994; *Nura A. Karim et al. NK 255* — 14 December 1995.
Distribution: Peninsular Thailand, Sumatra, Java, Peninsular Malaysia, Singapore, Borneo, the Philippines and Sulawesi.

Apocynaceae *Kibatalia maingayi* (Hook. *f.*) Woodson
Nee Soon, Central Catchment Nature Reserve *Wong, Ali & Chew 1* — 29 Oct 1992.
Also observed from Upper Seletar Reservoir Park and Nee Soon Firing Ranges.
Distribution: Sumatra, Peninsular Malaysia, Singapore, Banka and Borneo.

Apocynaceae *Urceola elastica* Roxb.
Bukit Timah Nature Reserve *E. Tang & Hj. Sidek Kiah 996* — 12 Oct 1995.
Distribution: Sumatra, Peninsular Malaysia and Singapore.

Asclepiadaceae *Gymnanthera oblonga* (Burm. *f.*) P.S. Green
Jurong, Science Centre *Jennifer Ng s.n.* - 1 April 1983; Changi Point mangrove *Ali Ibrahim AI 139* — Sept 1991; Changi (Loyang Avenue Swamp) *Joseph Lai & Samsuri LJ 282* — 25 Nov 1997.
Distribution: Thailand, Singapore, Java, the Philippines and south to northern Australia. The characteristic habitat of this species is the landward side of mangroves. The fact that it is not yet recorded from Peninsular Malaysia suggests that it has probably been overlooked rather than representing a gap in its geographic distribution.

Burseraceae *Dacryodes rugosa* (Blume) H.J. Lam
Bukit Timah Nature Reserve *Mohd Shah & Samsuri MS 3893* — 5 July 1976.
Distribution: S. Sumatra, Peninsular Malaysia, Singapore, W. Java and Borneo.

Cucurbitaceae *Gymnopetalum integrifolium* (Roxb.) Kurz
Singapore Quarry, Bukit Timah. *Ali Ibrahim & S.C. Chin AI 241* — 2 Sept 1994.
Distributiopn: W. India to Indo-China and south to Java.

Cucurbitaceae *Mukia maderaspatana* (L.) M.J. Roem.
Khatib Bongsu (secondary vegetation) *E. Tang & Hj. Sidek Kiah 1306* — 23 Feb 1998.
There is a single specimen from Malaysia, *J.G. Reed s.n.* — 7 April 1941, from Bagan Datoh, Perak. Apparently it is an incidental introduction from southern India as Reed records its name in Tamil as *Masu masukai.*
Distribution: India south to Australia.

Dipterocarpaceae *Dipterocarpus elongatus* Korth.
McRitchie Reservoir, Central Catchment Nature Reserve *J. Sinclair SFN 40673* – 14 July 1955, *T.C. Whitmore 66* – 14 Feb 1957; Mandai, Central Catchment Nature Reserve. *Wong, Ali & Chew 2* — 16 Nov 1992.
Distribution: E. Sumatra, E. Peninsular Malaysia, Singapore and Borneo.

Dipterocarpaceae *Shorea ochrophloia* Strugnell *ex* Symington
Mandai, Central Catchment Nature Reserve. *Ali Ibrahim et al. AI 24* — 7 July 1994.
Also observed from the MacRitchie area and Bukit Timah Nature Reserve.
Distribution: W. Sumatra, Peninsular Malaysia and Singapore.

Euphorbiaceae *Aporosa miqueliana* Mull.Arg.
Upper Pierce area, Central Catchment Nature Reserve. *Wong, Ali & Chew 4* — 14 Oct 1992.
Distribution: Sumatra, Peninsular Malaysia and Singapore.

Euphorbiaceae *Baccaurea brevipes* Hook. *f.*
Bukit Timah Nature Reserve. *E. Tang & Hj. Sidek 1040* — 9 Nov 1995, *1292* — 23 May 1996.
Distribution: Peninsular Malaysia, Singapore and Borneo.

Euphorbiaceae *Trigonostemon villosus* Hook. *f.*
Mandai, next to Mandai Columbarium. *Joseph Lai & Ali Ibrahim LJ 22* — 11 Dec 1995; Mandai, Central Catchment Nature Reserve. *Joseph Lai & Ali Ibrahim LJ 80* — 15 Oct 1996.
Distribution: Peninsular Malaysia (south from Perak and Trengganu) and Singapore.

Guttiferae *Garcinia maingayi* Hook. *f.* var. *stylosa* King
Both the species and variety are new records for Singapore.
Seletar, Central Catchment Nature Reserve. *Wong, Ali & Chew 6* — 21 Dec 1992.
Distribution: This variety is confined to Peninsular Malaysia (Perak and Johore) and Singapore.

Leguminosae *Intsia palembanica* Miq.
In Singapore, this species is represented by a majestic individual on the summit of Bukit Timah Hill, identified by Ali Ibrahim.
Distribution: Thailand to W. New Guinea.

Meliaceae *Aglaia leucophylla* King
Mandai, Central Catchment Nature Reserve. *Wong, Ali & Chew 9* — 23 Nov 1992.
Distribution: Sumatra, Peninsular Malaysia, Singapore, Borneo and the Philippines.

Meliaceae *Aglaia malaccensis* (Ridl.) Pannell
Bukit Timah Nature Reserve *Liew SFN 37278* — 4 July 1941; MacRitchie area, Central Catchment Nature Reserve. *Wong, Ali & Chew 17* — Oct 1992; Bukit Kallang, Central Catchment Nature Reserve. *Joseph Lai & Ali Ibrahim LJ 94* — 29 Oct 1996.
Distribution: Peninsular Malaysia, Singapore and Borneo.

Meliaceae *Chisocheton sarawakanus* (C. DC.) Harms
Mandai, Cantral Catchment Nature Reserve. *Wong, Ali & Chew 10* — 23 Nov 1992.
Distribution: Peninsular Malaysia, Singapore, Banka and Borneo.

Pandaceae *Galearia maingayi* Hook. *f.*
Botanic Gardens Jungle *E.J.H. Corner SFN 32519* — 16 Nov 1936; Bukit Timah Nature Reserve *E.J.H. Corner SFN 33588* — 6 July 1937, *SFN*

36410 – 25 April 1939.
Distribution: Sumatra, Peninsular Malaysia, Singapore and Borneo.

Piperaceae *Piper macropiper* Pennant
Bukit Mandai *Nangchi s.n.* — 19 April 1887; Krangi Forest Reserve *J.S. Goodenough s.n.* — 8 April 1890; Tuas *J.S. Goodenough 4684* — 29 May 1890; Chan Chu Kang *H.N. Ridley 6153* — 1894, *s.n.* — Feb 1896; Bukit Timah Nature Reserve *Chew W.L. 1442* — 30 May 1967; Nee Soon Firing Ranges, Central Catchment Nature Reserve *Joseph Lai LJ 99* — 5 Nov 1996.
Distribution: India and Sri Lanka, south to New Guinea and the Solomon Islands.

Polygalaceae *Xanthophyllum amoenum* Chodat
Bukit Timah Nature Reserve *E.J.H. Corner s.n.* — Nov 1943; McRitchie area, Central Catchment Nature Reserve. *Wong, Ali & Chew 12* — 17 Sept 1992.
Distribution: Peninsular Malaysia, Singapore, Riouw and Borneo.

Rubiaceae *Geophila repens* (L.) I.M. Johnst. var. *asiatica* (Cham. & Schltdl.) Fosberg
Fort Canning Park *Ali Ibrahim & Saifuddin AI 279* — 17 March 1998.
This species is quite widespread in Singapore and populations are known from Fort Canning Park, Makeway Avenue, Mount Emily Park and Pearl's Hill City Park.
Distribution: Indo-Malaya and China, south to Peninsular Malaysia, Singapore and Java.

Rubiaceae *Hedyotis verticillata* (L.) Lam
Chua Chu Kang *Ridley s.n.* — Feb 1894; Sultan of Johore's Land, Tanglin *Joseph Lai LJ 114* — 12 Dec 1996.
Distribution: India to Java.

Sapindaceae *Lepisanthes senegalensis* (Poir.) Leenh.
Mandai Road, Track 7 *Joseph Lai LJ 181* — 11 Feb 1997.
Also observed from MacRitchie area, Central Catchment Nature Reserve.
Distribution: Africa to New Guinea.

Sterculiaceae *Pterospermum lancifolium* Roxb.
Singapore (locality and collector unknown) *Accession No. 075943, 075944* — 1880s; Fort Canning Road *Ridley s.n.* — 1902, *Joseph Lai LJ 180* — 10 Jan 1997.
Distribution: India (NW Himalayas), Myanmar, Thailand and Peninsular Malaysia. Singapore appears to be the southernmost locality for this species.

Zingiberaceae *Scaphochlamys tenuis* Holttum
Bukit Timah Nature Reserve *H. Kennedy & E.P. Tay 4462A* — 16 Aug 1983.
Distribution: Peninsular Malaysia (previously known only from the type collection from Trengganu) and Singapore.
This is the first record of the genus *Schaphochlamys* from Singapore and was identified by Kai Larsen. Another plant with the same number (*4462B*) was tentatively identified by Kai Larsen as *Schaphochlamys* aff. *breviscape* Holttum but this has yet to be confirmed.

Acknowledgement

We are grateful to Ruth Kiew for help in writing this paper.

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The Angiosperm Flora of Singapore Part 6 Caesalpiniaceae

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Major references: R.Br. in M. Flinders, Voy. Terra austral. 2 (1814) 550; R.S. Cowan in Polhill & Raven (eds.) 1(1981) 57–64; L. Watson & Dallwitz, Gen. Leg. — Caesalpinioideae (1983) 95 pp.; Ding Hou, K. Larsen & S.S. Larsen, Fl. Males. 1:12 (1996) 409–730.

Caesalpinioideae Kunth

Trees, lianas or herbs to shrubs; evergreen or deciduous, armed (*Caesalpinia*) or not, rarely tendrilled (*Bauhinia*); sometimes buttressed (*Koompassia*, *Intsia*). *Leaves* simple, pinnate or bipinnate; alternate; petiolate; pinna and pinnules usually stalked, stipleless; extrafloral glands sometimes present on leaves (*Intsia*) or leaf-axes (*Chamaecrista*, *Senna*); stipules paired, usually caducous. *Inflorescence* a raceme or panicle, singly or in fascicles; axillary, terminal on branches, or cauliflorous. *Flowers* usually bisexual, rarely unisexual (*Caesalpinia bonduc*), zygomorphic, usually 5-merous except for the gynoecium, perigynous; sepals (4-)5, usually free, rarely connate to form a calyx tube, usually imbricate; petals 5, sometimes reduced to (1–) 4 or absent (*Dialium*), imbricate, the adaxial petal overlapped by lateral petals (when these are present), often clawed, often unequal; stamens 10, or through reduction 9, 7–2, or in female flowers absent, filaments free or basally connate, anthers basi- or dorsi-fixed, often versatile, longitudinally dehiscent or by apical (and basal) pores; ovary 1-loculate, with 1or few to many anatropous ovules often superposed in 2 rows on either side of the adaxial suture, usually flattened, stipitate to sessile; style often recurved, short or long; stigma capitate or peltate, large to indistinct; hypanthium usually cupular, ± oblique, short. *Fruit* a legume, drupe (*Dialium*) or samara (*Koompassia*); legume compressed, oblong to linear, indehiscent or not, valves chartaceous, coriaceous or woody; drupes and samaras, indehiscent, rarely with pulp (*Dialium*), glabrous, pubescent to spinescent. *Seeds* 1–many per legume, varying in shape, often flattened, exendospermous; testa membraneous, coriaceous or crustose, rarely areolate (*Senna*), rarely arillate (*Sindora*); cotyledons fleshy or foliaceous, radicle straight.

Distribution — Predominantly tropical group of c. 160 genera with c. 2000 spp. (Hou *et al.*, 1996). In Singapore, there are 10 genera with 20 spp.

Ecology — Wide range of habitats including primary and secondary forest, coastal beach forest, mangrove, wasteland, abandoned villages and farmland.

Uses — See under species.

Notes — This family has traditionally been treated as a subfamily (Caesalpinioideae) of the family Leguminosae (e.g., Bentham (1865), Taubert (1894), Whitmore (1973) and Corner (1988) but here treated as a family in agreement with Cronquist (1981) and Hou *et al.* (1996). The primary reason is the distinction between three basic groups within the legumes *sensu lato* is clear. Moreover, in this treatment no emphasis is laid on the borderline Dimorphandra group *sensu* Polhill and Vidal (between Mimosaceae and Caesalpiniaceae) and tribe Swartzieae (between Caesalpiniaceae and Papilionaceae) as they are not found in Singapore.

Key to the Genera

1a. Leaves simple; lamina bilobed with an apical sinus a quarter to a third of the lamina length, venation palmate; tendrilled ..... ***Bauhinia***
1b. Leaves pinnately compound; pinna or pinnule lamina margins entire, venation pinnate; not tendrilled 2

2a. Leaves bipinnate 3
2b. Leaves pinnate 4

3a. Prickly climbers (rarely shrubs or trees). Lowermost sepal mostly cucullate. Stigma small, as wide as the style ..... ***Caesalpinia***
3b. Unarmed trees. Lowermost sepal unmodified. Stigma large, peltate ..... ***Peltophorum***

4a. Leaves imparipinnate 5
4b. Leaves paripinnate 6

5a. Midrib minutely puberulous above. Petals 5. Fruit a samara ..... ***Koompassia***
5b. Midrib glabrous above. Petals absent. Fruit a drupe ..... ***Dialium***

6a. Trees. Legumes oblong, orbicular or subglobose, 1–6-seeded 7
6b. Herbs to shrubs. Legumes long and narrow, >10-seeded 9

7a. Pinnae unequal, lowermost pair if present usually very much smaller. Petals (4-)5. Legume subglobose, deeply rugose ..... ***Cynometra***
7b. Pinnae ± equal, lowermost pair not markedly smaller than the others. Petal 1. Legume flattened, smooth or spinescent 8

8a. Pinnae with a thickened marginal nerve. Fertile stamens usually 9, basally connate into a hirsute sheath. Legume elliptic to orbicular. Seeds arillate ..... ***Sindora***
8b. Pinnae without a thickened marginal nerve. Fertile stamens 3(–4), free. Legume oblong. Seeds exarillate ..... ***Intsia***

9a. Pinnae linear or falciform, sessile. Anther-thecae ciliate along the sutures. Legume elastically dehiscent, valves coiling ..... ***Chamaecrista***
9b. Pinnae (oblong-)elliptic, ovate or obovate, stalked. Anther-thecae glabrous. Legume either indehiscent or dehiscent through 1 or both sutures, valves not coiling ..... ***Senna***

Bauhinia L.

Sp. pl. 1 (1753) 374; DC., Prodr. 2 (1825) 512; R.P.Wunderlin, K. Larsen & S.S. Larsen, Biol. Skr. danske Vidensk Selsk. 28 (1987) 18; Watson & Dallwitz, Gen. Leg. – Caesalpinioideae (1983) 12, 47.

Bauhinia subg. *Phanera* sect. *Phanera* (Lour.) Wunderlin, Larsen & Larsen

Phanera subg. *Phanera* sect. *Meganthera* de Wit

Tendrilled lianas; stem dbh ≤15 cm, young branches brownish pubescent, later glabrous. *Leaves* simple; lamina bilobed, palmately nerved, glabrous above, mucronate; petiole brownish pubescent; stipules ovate, falcate, puberulous, caducous. *Raceme* terminal or axillary, axis rusty brown to silvery pubescent. *Flowers* bisexual, zygomorphic, alternate; bracts lanceolate, early caducous; bracteoles linear, early caducous; calyx 5-lobed, sepals longer than the hypanthium, rusty brown or silky white pubescent outside; petals 5, shortly clawed, subequal, standard smaller with a hairier claw; stamens 3, staminodes 2–3, anthers dorsifixed and versatile, dehiscence

longitudinal; ovary densely pubescent, stipitate; style widened just before the peltate and capitate stigma; hypanthium long tubular with an orifice near the standard; flower buds oblong-apiculate. *Legume* tardily dehiscent, valves woody. *Seeds* ellipsoid to orbicular, flat with short funicular aril-lobes.

Distribution — *Bauhinia s. l.* has about 300 spp. all over the tropics with 69 spp. in Malesia and the section *Phanera sensu* Wunderlin, Larsen & Larsen has about 60 spp. in South and South-east Asia (Larsen and Larsen, 1996). In Singapore there is only one indigenous species.

Ecology — Lianas in primary and secondary forests, also in freshwater swamps; fringing the forests or along trails and streams.

Uses — Various *Bauhinia* spp. are used as ornamental trees (*B. purpurea* L., *B. variegata* L.), shrubs (*B. acuminata* L.) or climbers (*B. kockiana* Korth.).

Notes — In the past, some authors split *Bauhinia s. l.* into several distinct genera (e.g., de Wit (1956) who recognized 7 genera) as this large genus included a wide range of habits like lianas, shrubs or trees. More recently, Larsen & Larsen (1996) studied the genus throughout its distribution and found it to be a natural group with a reticulate pattern of variation. *Bauhinia ferruginea* var. *griffithiana* (*A.H.B. Loo & T.M. Leong ALoo 064*) was found near the Visitors' Centre of Bukit Timah Nature Reserve. Although it is not considered a native or naturalized species in Singapore, it regenerates within the vicinity of adult plants; so its distribution in Singapore should be monitored over time to see if this species becomes naturalized.

1. *B. semibifida* Roxb. ex Roxb. *var. semibifida*

Fl. Ind., ed Carey, 2 (1832) 330; Ridl., J. Straits Br. R. Asiat. Soc. 33 (1900) 75; Ridl., Fl. Malay Penins. 1 (1922) 627; de Wit , Reinwardtia 3 (1956) 465; H. Keng, Gdns' Bull., Singapore 27 (1974) 256; H. Keng, Concise Fl. Singapore (1990) 32; I.M. Turner, K.S. Chua & H.T.W. Tan, J. Singapore natn. Acad. Sci. 18 & 19 (1990) 72; I.M. Turner, Gdns' Bull., Singapore 45 (1993) 118; I.M. Turner, Gdns' Bull., Singapore 47 (1995) 294; Ding Hou, K. Larsen & S.S. Larsen, Fl. Males. 1:12 (1996) 492.

Phanera semibifida (Roxb.) Benth.

Figure 1. ***Bauhinia semibifida*** **Roxb. ex Roxb. var.** ***semibifida.*** a. Inflorescence; b. Split legumes with valves open and separate showing seeds; c. Flower bud; d. Top view of flower; e. Left, leaf from a flowering branch (abaxial); right, leaf from a vegetative branch (adaxial); f. Left, complete half-flower; right - mature standard petal having turned yellow from white. (Each interval on scale bar equivalent to 1 mm). (A.H.B. Loo, A. Ibrahim, E.E.L. Seah & J. Lai A.Loo 084)

Young branches brownish pubescent. *Laminas* orbicular, 4–9 cm across, chartaceous, 11-nerved, brownish pubescent below, apical sinus a quarter to a third the lamina length, tips obtuse to subacute, base cordate; petiole 1–5 cm long, pubescent; stipules c. 2 by 1 mm. *Raceme* to 45 cm long, rusty tomentose. *Flowers* fragrant; sepals 5, reflexed, lanceolate, c. 2 cm long, caducous; petals 5, white turning yellow, oblanceolate with a short claw, 20–40 by 8–13 mm, claw and the base of the midrib puberulous; stamens 3, filaments white, 1–2.5 cm long, anthers dorsifixed, versatile, c. 1 cm long; staminodes to 1 cm long; ovary 2–4 cm long, silky tomentose, stipitate; stigma, white-green, c. 1 cm long; receptacle tubular; pedicel 2–5 cm long. *Legume* flat, oblong, c. 10 by 4 cm. *Seeds* 4–6 per legume, flat, hilum seven eighths the seed circumference.

Distribution — Singapore: fairly common; Botanic Gardens' Jungle, Bukit Kallang, Central Catchment Nature Reserve, Clementi Road; previously found in Bukit Mandai, Bukit Timah. Sumatra, Peninsular Malaysia, Borneo, Philippines, Celebes (Larsen and Larsen, 1996). The most widespread species of the genus.

Ecology — Forest edge and streams; flowering in June to July, October to December. Legumes reach maturity about one month after flowering. Ants are attracted to the secretions from the flowers and Lepidopteran larvae were observed on the peltate stigma which had a clear sticky secretion. Dispersal is by explosion and torsion of the legumes (Ridley, 1930).

Uses — Pounded roots are used as a treatment for veneral disease (de Wit, 1956).

Notes — There are five other varieties occurring in Malesia (four in Borneo and one in the Philippines). Throughout its distribution, var. *semibifida* is distinguished from the others in having a long tubular hypanthium dilated at the base (versus a short, uniformly wide hypanthium) , leaves on flowering shoots 4–11 cm across (versus leaves 11–18 cm across) and the apical sinus 1/4–1/2 the leaf length (versus a deep apical sinus more than 1/2 the leaf length).

Caesalpinia L.

Sp. pl. (1753) 380; Gen. pl. ed. 5 (1754) 178; Hattink, Reinwardtia 9 (1974) 1–69; Polhill and Vidal in Polhill and Raven (eds.), Adv. Leg. Syst. 1 (1981) 93.

Cinclidocarpus Zoll.
Guilandinia L.
Mezoneuron Desf.
Poinciana L.

Lianas or half-climbers, armed with recurved or straight prickles. *Leaves* bipinnate; rachis armed with paired prickles below the insertion of pinnae and pinnules with scattered ones in between; pinnae opposite; pinnules opposite, alternate or rarely subopposite, sessile or subsessile. *Inflorescence* a raceme or panicle (raceme of racemes); axillary, terminal or rarely supra-axillary; bracts mostly caducous; bracteoles absent. *Flowers* usually bisexual, sometimes unisexual, zygomorphic; sepals 5, free or connate, subequal, lower one usually cucullate; petals 5, yellow, orange, pink or rarely green, usually spathulate, clawed, unequal, standard differing in shape and size; stamens 10, free, equal or alternately narrow and wide, anthers dorsifixed and longitudinally dehiscent; ovary flat, sessile or subsessile; style ± curved upwards, slender; stigma usually as wide as the style; hypanthium oblique, cupular; pedicels sometimes articulated. *Legumes* usually smooth or sometimes armed with spines, winged along the dorsal suture or not, dehiscent or not. *Seeds* 1–8 per legume, orbicular to oblong, flat or globose.

Distribution — Pantropical genus with 18 indigenous species found all over Malesia (Hou, 1996a). Four indigenous species are found in Singapore.

Ecology — The Singapore species are found in beach forest and back-mangrove or further inland, in primary or secondary forests along trails or near streams.

Uses — See under individual species.

Notes — Recurved prickles may be set on top of woody triangular knobs in old stems for *C. crista* (Fig. 2) and *C. sumatrana*.

Key to Species

1a. Stipules pinnatifid, large, each lobe orbicular to 2.5 cm across; pinnae prolonged to a c. 5 mm long mucro. Branches pubescent, armed with straight and recurved prickles. Flowers unisexual (in male flowers, carpel rudimentary, 1–2 mm long; in female flowers anthers without

pollen); ovary densely spiny; petals green-yellow; style pubescent. Legumes densely spiny, pubescent, dehiscent. Seeds with lines concentric about the hilum ..... **1. *C. bonduc***

1b. Stipules simple and triangular, minute or absent, c. 1 by 1 mm; pinnae not prolonged into a mucro. Branches glabrous, armed only with recurved prickles. Flowers bisexual, ovary inermous; bracts inconspicuous or early caducous, 1–2 mm long, straight, not longer than bud; petals orange, pink or yellow; style glabrous or only sparsely puberulous basally. Legumes inermous, glabrous, indehiscent. Seeds without concentric lines 2

2a. Pinnules sessile, 2–6 mm wide, linear, base oblique and truncate, tapering to a point or a minute mucro on the distal side, in 12–30 pairs per pinna, membranous; rachis pubescent, 30–45(–70) cm long. Branchlets lenticellate. Petals orange. Legumes often twisted, base rounded. Seeds subglobose, c. 10 mm across ..... **4. *C. tortuosa***

2b. Pinnules with a 2–4 mm long stalk, 10–50 mm wide, elliptic or ovate-elliptic or oblong, base cuneate, not tapering on any side, in 1–6 pairs per pinna, subcoriaceous to coriaceous; rachis glabrous, 10–30 cm long. Branchlets without lenticels. Petals yellow or pink. Legumes not twisted, base cuneate. Seeds flat, c. 1–5 mm thick 3

3a. Pinnules alternate (but topmost pair often opposite), in 3–6 pairs per pinna, widely elliptic to oblong, dull above, sometimes puberulous below, apex retuse or rounded; pinnae in 4–8 pairs. Petals pink; sepals connate to a campaniform calyx tube. Legumes chartaceous, winged dorso-longitudinally (c. 1 cm wide), 10 cm long or more, apex rounded or hooked. Seeds 1–8 per legume, clearly outlined on the surface of the legume. Ovary glabrous, slightly falcate; filaments laterally compressed, alternately a narrow and wide one, glabrous or puberulous basally ..... **3. *C. sumatrana***

3b. Pinnules opposite, in 1-3 pairs pairs per pinna, elliptic to ovate elliptic, shiny above, glabrous on both surfaces, apex obtuse, acute or acuminate; pinnae in 2–4 pairs. Petals yellow; sepals free, not forming a calyx tube. Legumes woody, not winged, 7 cm long or less, apex beaked. Seeds 1(–2) per legume, not outlined on the surface of the legume. Ovary puberulous, straight; filaments terete, pubescent to above the middle ..... **2. *C. crista***

1. *C. bonduc* (L.) Roxb.

Fl. Ind., ed. Carey, 2 (1832) 362; L., Sp. pl., (1753) 381; Ridl., Fl. Malay

Penins. 1 (1922) 649; Hattink, Reinwardtia 9 (1974) 17; H. Keng, Gdns' Bull., Singapore 27 (1974) 256; K. Larsen, S.S. Larsen & J.E. Vidal, Fl. Thailand 4 (1984) 72; H. Keng, Concise Fl. Singapore (1990) 32; I.M. Turner, K.S. Chua & H.T.W. Tan, J. Singapore natn. Acad. Sci. 18 & 19 (1990) 72; I.M. Turner, Gdns' Bull., Singapore 45 (1993) 118; I.M. Turner, Gdns' Bull., Singapore 47 (1995) 295.

Half-climbers to 15 m long. *Leaves*: rachis 15–80 cm long; pinnae in 3–9 pairs, 8–18 cm long; pinnules in 5–10 pairs per pinna, opposite or rarely subopposite, elliptic-oblong, 2–5.5 by 1–2 cm, pubescent to glabrous, apex mucronate, stalk 1–2 mm long. *Panicle* supra-axillary or terminal, 12–60 cm long, pubescent. *Flowers*: sepals ovate, equal or rarely subequal, 7–9 by 3–4 mm, pubescent; standard petal: limb reflexed, with red patches, 4–5 by 3–4 mm, claw 3–4 by 1–2 mm, other 4 petals: spathulate, 8–10 by 3–4 mm (including c. 2 mm long, woolly claw); stamens 6–10 mm long (in female flowers 5–6 mm long staminodes), lower half woolly, anthers c. 1 mm long; ovary c. 3 by 2 mm; style 3–4 mm long; stigma ciliate; pedicel 4–5 mm long, articulated. *Legume* oblong, 6.5–9 by 3.5–4.5 cm, stipitate to 6 mm long, remnant style c. 10 mm long. *Seeds* 1–2 per legume, grey, globular, 1.5–2 cm across.

Distribution — Singapore: only two plants known; Pulau Sakijang Pelepah (extreme South), Pulau Semakau (North-west). Previously found in East Coast Park beach, Pulau Senang (South-east side). Pantropical; in Malesia all parts, but distinctly scarce in the rain forests of Sumatra, Borneo, the Philippines and western New Guinea (Hattink, 1974).

Ecology — Coastal, beach forest and back-mangrove to inland, in secondary forests. Flowers and fruits can occur together without periodicity. Legumes dispersed by floating in the sea (Ridley, 1930).

Uses — The seeds are used as an anthelminthic, vermifuge, chewed for coughs or eaten for stomach trouble as well as for curing gout (Burkill, 1935). The attractive, hard seeds are used ornamentally as beads in necklaces, rosaries and also used as marbles (Rudd, 1991), hence the name "grey knicker" which refers to the game of marbles played by children. In Somoa and Tonga, the prickly stems, attached to a stick are used to snare fruit bats (Whistler, 1992).

2. *C. crista* L.

Sp. pl. (1753) 380; Ridl., J. Straits Br. R. Asiat. Soc. 33 (1900) 75; Ridl., Fl.

Figure 2. ***Caesalpinia crista*** **L.** Stem showing characteristic recurved prickles set on top of corky knobs.

Malay Penins. 1 (1922) 650; Sinclair, Gdns'. Bull., Singapore 14 (1953) 32; Backer & Bakh. *f.*, Fl. Java 1 (1964) 545; Hattink, Reinwardtia 9 (1974) 20; H. Keng, Gdns' Bull., Singapore 27 (1974) 256; K. Larsen, S.S. Larsen & J.E. Vidal, Fl. Thailand 4 (1984) 70; H. Keng, Concise Fl. Singapore (1990) 32; I.M. Turner, K.S. Chua & H.T.W. Tan, J. Singapore natn. Acad. Sci. 18 & 19 (1990) 72; I.M. Turner, Gdns' Bull., Singapore 45 (1993) 118; I.M. Turner, Gdns' Bull., Singapore 47 (1995) 295.

Caesalpinia nuga (L) Ait.f.

Lianas to 15 m long; branchlets glossy. *Leaves*: rachis 10–30 cm long; pinnae 3.5–9 cm long; pinnules opposite or rarely subopposite, 2–12.5 by 1–5 cm, subcoriaceous, base cuneate or rounded; petiolules 2–4 mm long; stipules, triangular, c. 1 by 1 mm, caducous. *Panicle* axillary or terminal, 15–40 cm long; bracts c. 1mm long, caducous. *Flowers*: sepals unequal, 7–8 by 2–3 mm (lowest one cucullate); standard petal: limb reflexed, orbicular, c. 5 mm across, claw c. 5 by 2 mm, pubescent, other 4 petals: obovate, 8–10 by 5–6 mm (including c. 2 mm long pubescent claw); stamens 10–14 mm long, anthers c. 1 mm long; ovary c. 5 by 2 mm; style c. 8 mm long, glabrous; stigma ciliate; pedicel 5–15 mm long, articulated c. 1 mm below

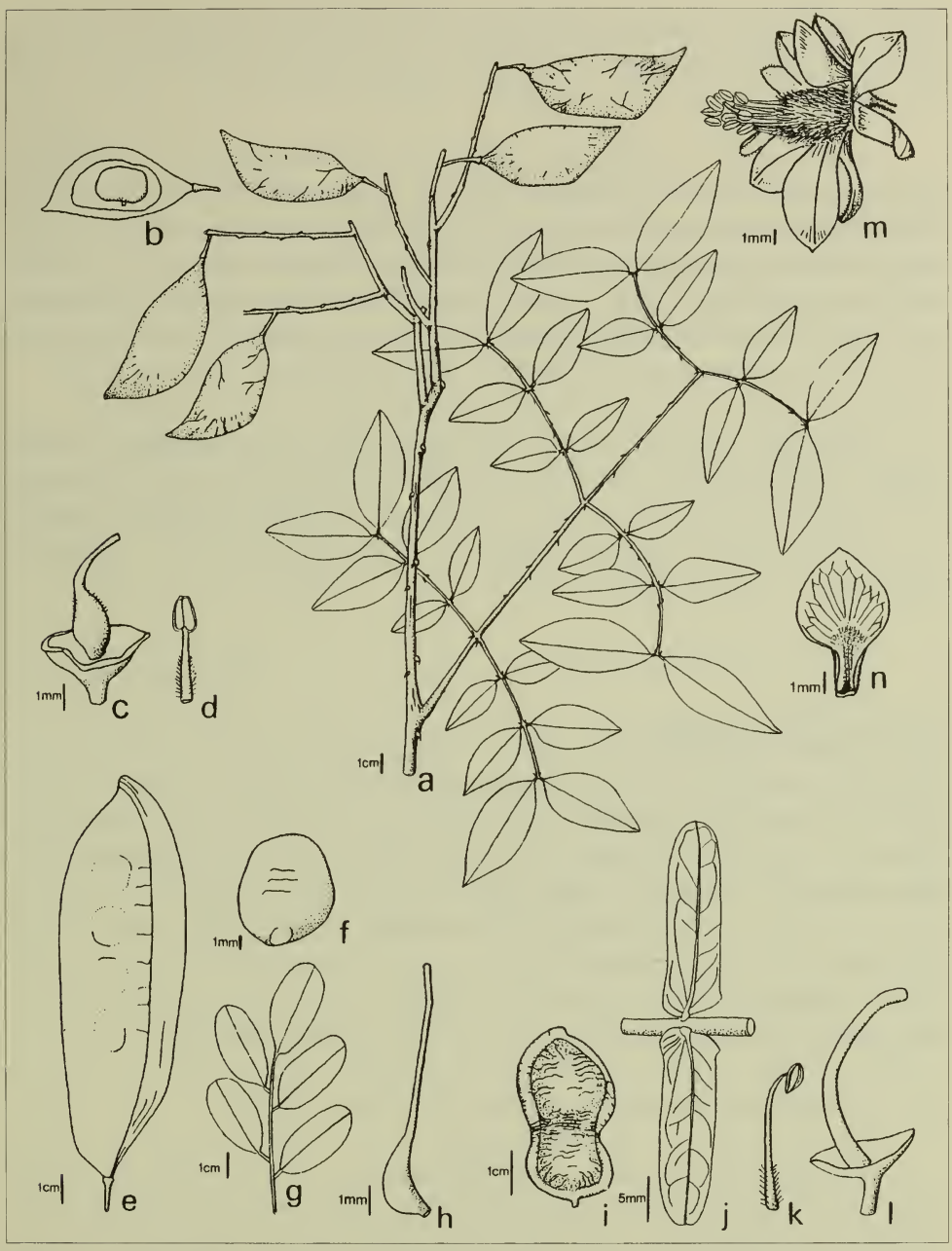

Figure 3. ***Caesalpinia crista*** **L.** a. Fruiting branch; b. Legume with one side removed to show seed (Tanaka, Chen & Boo A.Loo 005); c. Isolated carpel on hypanthium; d. Isolated stamen (SING 078418); m. Side view of flower; n. Standard petal (After Verdcourt, 1979). *Caesalpinia sumatrana* Roxb. e. Winged legume; f. Seed; g. Alternate pinnules of a pinna (H. N. Ridley 2105); h. Isolated falcate ovary (Mat 6028). *Caesalpinia tortuosa* Roxb. i. Legume; j. One pair of sessile pinnules; k. Isolated stamen; l. Isolated carpel on hypanthium. (King's Collector L10014).

the flower. *Legume* green turning brown, subelliptic or rhombic, flat, 4–7 by 3–4 cm, smooth, veined. *Seeds* brown, orbicular to reniform, 2–2.5 by 1.5–2 by 0.5–1 cm.

Distribution — Singapore: fairly common; Pulau Sakijang Pelepah, Pulau Semakau (West), Pulau Tekong, Pulau Tekong Kechil, Pulau Terkukor, Sembawang Road end, Sungei Buloh Nature Park, Sungei Mandai Kechil (Kampong Fatimah), Western Catchment Area; previously collected in Jurong, Kranji. Coastal parts of South-east Asia from India to the Ryuku Islands, Australia (Queensland), Palau Island, New Caledonia; all over Malesia except East Sumatra and East Borneo (Hattink, 1974).

Ecology — River banks, sandy beaches, in back-mangrove and its fringes. Mature plants may have stems to c. 10 cm thick that are covered by triangular woody knobs with recurved prickles set at the tip (Fig. 2). Periodicity for flowering and fruiting not found (Hattink, 1974). Legumes dispersed by floating (Ridley, 1930).

Uses — As for *C. bonduc.*

3. *C. sumatrana* Roxb.

Fl. Ind., ed. Carey 2 (1832) 366; Baker in J.D. Hook., Fl. Brit. India 2 (1879) 259; Ridl., J. Straits Br. R. Asiat. Soc. 33 (1900) 75; Ridl., Fl. Malay Penins. 1 (1922) 647; Backer & Bakh. *f.*, Fl. Java 1 (1964) 546; Hattink, Reinwardtia 9 (1974) 55; I.M. Turner, K.S. Chua & H.T.W. Tan, J. Singapore natn. Acad. Sci. 18 & 19 (1990) 72; H. Keng, Gdns' Bull., Singapore 27 (1974) 262; H. Keng, Concise Fl. Singapore (1991) 36; I.M. Turner, Gdns' Bull., Singapore 45 (1993) 118; I.M. Turner, Gdns' Bull., Singapore 47 (1995) 295; Ding Hou, Fl. Males. 1:12 (1996) 553.

Mezoneuron sumatranum (Roxb.) W. & A. ex Miq.

Climbers to 20 m long; branchlets glossy. *Leaves*: rachis 16–20 cm long; pinnae 6–15 cm long; pinnules 2–7 by 1–5.5 cm, subcoriaceous, apex sometimes shortly mucronate, base cuneate to rounded; petiolules 2–4 mm long. *Panicle* supra-axillary or terminal, 30–80 cm long; bracts c. 1 by 0.5 mm, caducous. *Flowers*: calyx tube red, c. 1.3 by 0.5 cm, circumscissle above the hypanthium and falling off with the corolla and stamens, calyx lobes half-orbicular, 3–10 mm long, lowest one cucullate; petals spathulate, subequal, 12–30 mm long, limb 8–12 mm wide, basal part 2–3 mm wide; filaments pale pink, 10–29 mm long, anthers 1.5–3 mm long; ovary falcate,

4–15 by 1–2 mm; style 6–15 by 0.5 mm; stigma ciliate; pedicel 5–20 mm long. *Legume* wine-red, oblong, 10–17 by 3–6 cm (including the c. 1 cm wide wing). *Seeds* brown, broadly elliptic, 9–11 by 7 by 1 mm, smooth, margins nerved.

Distribution — Singapore: rare, Bukit Timah Nature Reserve (along the Rock Path and Cave Path); previously collected in Kranji, Sungei Jurong. Possibly collected in India. Malesia: Sumatra (West Coast Bengkulu), Peninsular Malaysia, West and East Java, Borneo (near Sandakan); New Guinea, Solomons (Guadalcanal) (Hattink, 1974).

Ecology — Forest fringes, along forest trails and in late secondary forests. Like *C. crista*, mature climbers of *C. sumatrana* also have thick stems with recurved prickles set on top of woody knobs. The knobs of this species are more closely set than in *C. crista*.

Uses — None known.

4. *C. tortuosa* Roxb.

Fl. Ind. ed. Carey 2 (1832) 365; Baker in J.D. Hook., Fl. Brit. India 2 (1879) 256, 257; Ridl., J. Straits Br. R. Asiat. Soc. 33 (1900) 75; Ridl., Fl. Malay Penins. 1 (1922) 651; Hattink, Reinwardtia 9 (1974) 57; H. Keng, Gdns' Bull., Singapore 27 (1974) 256; I.M. Turner, K.S. Chua & H.T.W. Tan, J. Singapore natn. Acad. Sci. 18 & 19 (1990) 72; H. Keng, Concise Fl. Singapore (1991) 32; I.M. Turner, Gdns' Bull., Singapore 45 (1993) 118; I.M. Turner, Gdns' Bull., Singapore 47 (1995) 295.

Lianas, shrubs or small trees to 10 m tall. *Leaves*: pinnae in 7–20 pairs, 6–10.5 cm long; pinnules 10–13(–22) by 2–6 mm, glabrous or sparsely puberulous below, apex rounded to obtuse; stipules absent. *Panicle* axillary, terminal or rarely supra-axillary, 20–60 cm long; bracts 2 by 1 mm, pubescent. *Flowers*: sepals ovate, unequal, 8–10 by 4–6 mm, ciliate (lowest deeply cucullate); petals unequal, standard: limb reflexed, orbicular, c. 5 mm in diam., claw 5–8 by 2 mm, hirsute above, other 4 petals: limb orbicular to reniform, 7–10 by 6–12 mm, claw 1–3 by 1 mm, hirsute or glabrous; stamens slightly exserted, filaments 10–15 mm long, woolly halfway, anthers 2.5–3 by 1 mm; ovary subsessile, 3–5 by 1–1.5 mm, hairy or glabrous; style 8–12 mm, sparsely puberulous basally; stigma c. 1 mm across; pedicel 8–15 mm long, pubescent. *Legumes* black when dry, oblong, 3.5–9 by 2–3.5 cm, sutures thickened, constricted between the seeds, apex obtuse, shortly beaked. *Seeds* 1–5(–7) per legume.

Distribution — Singapore: now extinct; previously collected in Changi (Loyang). India (Assam), Hong Kong, Burma; Malesia: West and East Sumatra, Peninsular Malaysia (Johore, Penang), West and East Java, Kalimantan (Hattink, 1974).

Ecology — Primary and secondary forests, forest fringes, along rivers.

Uses — None known.

Chamaecrista Moench

Methodus (1794) 272; de Wit, Webbia 11 (1955) 278; Irwin and Barneby in Polhill and Raven (eds.) Adv. Leg. Syst. 1 (1981) 106, Mem. N. Y. bot. Gdn 35 (1982) 636.

Cassia subg. *Lasiorhegma* Vogel ex Benth.

Herbs with a woody base; stem erect or decumbent, pubescent. *Leaves* paripinnate; rachis with longitudinal ridges above, produced to a short mucro beyond the terminal pairs of pinnae; pinnae asymmetrical, sessile, apex ± mucronate, margins sparsely ciliate, base truncate; petiole with 1(–2) subsessile glands adaxially; stipules linear, apex acute, margins ciliate, intrastipular trichomes present. *Raceme* supra-axillary, few-flowered, bracts and bracteoles similar to the stipules but smaller. *Flowers*: sepals 5, unequal, membranous and thicker in the median undersurface, puberulous; petals 5, yellow, unequal, membranous, with darker reticulate veins visible, claw short; stamens 10, filaments straight, short, anthers basifixed, straight or ± curved, of ± two length classes, opening by two apical pores, thecae ciliate along the sutures. *Legume* strap-shaped, flat, transversely grooved between seeds, elastically dehiscent, valves twisting spirally. *Seeds* many per legume, seedcoat ± pitted, glossy.

Distribution — About 240 spp. are indigenous to the Americas with few indigenous to Tropical Asia (Larsen and Hou, 1996a). In Singapore, two exotic species. are naturalized (Corlett, 1988).

Ecology — Mainly found in open places, wasteland and reclaimed land. Roots have nodules.

Uses — Used mainly as green manure. See under species.

Notes — In the past, species in *Chamaecrista* and *Senna* were considered as subgenera under *Cassia* L. *s. l.* (e.g., de Wit, 1955). They are now recognized as separate genera following the work of Irwin and Barneby (1982) who raised the genus *Cassia s.l.* to the level of subtribe and elevated the previous subgenera to generic rank alongside *Cassia s.s.*. The circumscription of the genera follows that of Irwin and Barneby (1982) but the delimitation of species follows that of Larsen and Hou (1996a) who have found that Asian species justify the maintenance of both *C. leschenaultiana* and *C. mimosoides*.

Key to the Species

1a. Leaf rachis with 2 evenly high longitudinal ridges parallel to each other on the adaxial surface; pinnae falciform, 2–3 mm wide; subsessile discoid gland 1–1.5 mm below the lowest pair of pinnae. Ovary and legume with long, thin, non-appressed hairs; legume with a ± hooked mucro. Seeds 10–15 per legume ..... **1. *C. leschenaultiana***

1b. Leaf rachis with only one unevenly high longitudinal ridge in the form of an adaxial series of semicircular flaps between the nodes; pinnae linear, 0.5–1 mm wide; sessile discoid gland immediately below the lowest pair of pinnae. Ovary and legume with stiff, appressed hairs; legume with a ± straight mucro. Seeds 20–25 per legume..... ..... **2. *C. mimosoides***

1. *C. leschenaultiana* (DC.) O.Deg.

Fl. Haw. Fam. 169b. (1934); DC., Mem. Soc. Phys. Hist. Nat. Geneve 2 (1824) 132; Ridl., J. Straits Br. R. Asiat. Soc. 33 (1900) 74; Ridl., Fl. Malay Penins. 1 (1922) 619; de Wit, Webbia 11 (1955) 280; Rudd, Rev. Handb. Fl. Ceylon (1991) 88; I.M. Turner, K.S. Chua & H.T.W. Tan, J. Singapore natn. Acad. Sci. 18 & 19 (1990) 72; I.M. Turner, Gdns' Bull., Singapore 45 (1993) 119; I.M. Turner, Gdns' Bull., Singapore 47 (1995) 297; K. Larsen & Ding Hou, Fl. Males. 1:12 (1996) 566.

Cassia leschenaultiana DC.
Chamaecrista nictitans (L.) Moench

Subshrubs to 1.5 m tall; stem erect or decumbent, pubescent. *Leaves*: rachis 4–9 cm long, produced to a short mucro to 4 mm long; pinnae in 10–30 pairs, asymmetrical, 5–20 by 2–3 mm, apex truncate, mucro 0.5 mm long or more, margins sparsely ciliate, base truncate; petiole 5–7 mm long with

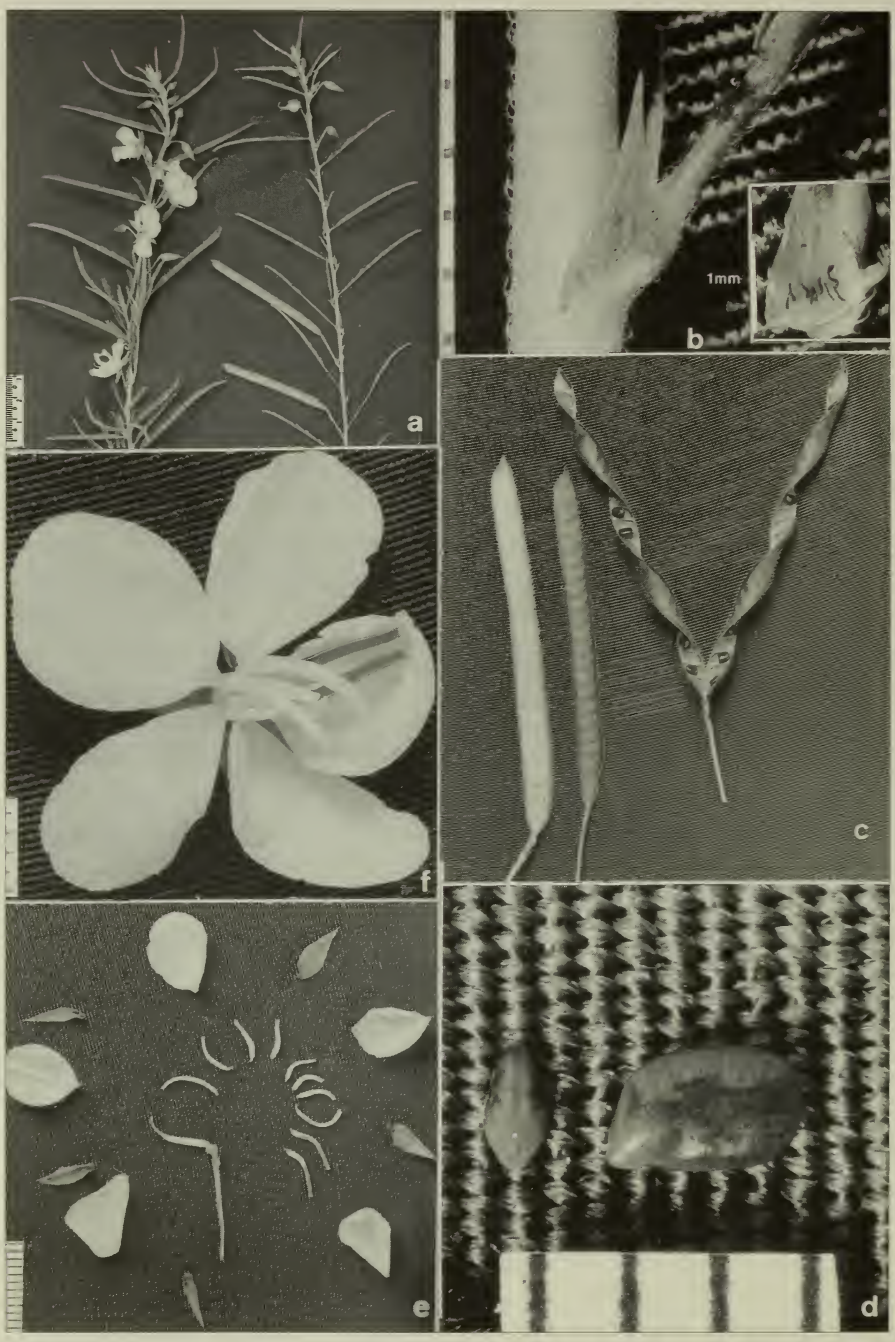

Figure 4. ***Chamaecrista mimosoides*** **(L.) Greene.** a. Left, flowering branch; right, fruiting branch; b. Paired stipules and petiolar gland, inset, intrastipular trichomes. c. From left, unripe, ripe and split legume showing spirally twisted valves; d. Hilar view and side view of seed; e. Exploded flower; f. Anterior view of flower. (Each interval on scale bar equivalent to 1mm). (A.H.B. Loo A.Loo 085).

1(–2) glands (c. 1 mm in diam.); stipules 10–17 mm long. *Raceme* 1–4-flowered. *Flowers*: sepals ovate to long–acute, 7–8 by 1–3 mm; petals orbicular to obovate, c. 7–8 by 3–6 mm; filaments short, c. 1 mm long, anthers slightly curved, unequal, 2–6 mm long; ovary c. 5 by 1 mm, sessile; style recurved, c. 2 mm long, glabrous; stigma flat, ciliate. *Legume* green turning brown, strap–shaped, 3–5 by 0.5 cm. *Seeds* dark brown, oblong, flat, c. 4 by 3 mm.

Distribution — Singapore: fairly common but less common than *C. mimosoides*; Pulau Tekong, Pulau Ubin (Western tip). South-east Asia, widespread in Malesia (Larsen and Hou, 1996a).

Ecology — Found in waste or reclaimed land; in Pulau Ubin growing in rock crevices near the sea. It has been observed to form nodules (Allen & Allen, 1981).

Uses — As green manure (Burkill, 1935).

2. *C. mimosoides* (L.) Greene

Pittonia 4 (1899) 27; L., Sp. pl. (1753) 379; Baker in J. D. Hook., Fl. Brit. India 2 (1879) 266; Ridl., Fl. Malay Penins. 1 (1922) 619; de Wit, Webbia 11 (1955) 283; M.R. Hend, Mal. Wild. Fl. Dic. (1959) 97; H. Keng, Gdns' Bull., Singapore 27 (1974) 258; R.T. Corlett, J. Biogeog. 15 (1988) 657–663; J.B. Hacker, A guide to herbaceous and shrub legumes of Queensland (1990) 94; H. Keng, Concise Fl. Singapore (1990) 33; I.M. Turner, K.S. Chua & H.T.W. Tan, J. Singapore natn. Acad. Sci. 18 & 19 (1990) 72; I.M. Turner, Gdns' Bull., Singapore 45 (1993) 119; I.M. Turner, Gdns' Bull., Singapore 47 (1995) 297; K. Larsen & Ding Hou, Fl. Males. 1:12 (1996) 567.

Cassia mimosoides L.

Subshrubs to 1.2 m tall; stem erect or decumbent, appressed pubescent. *Leaves*: rachis 3–5 cm long, produced to a short mucro to 3 mm long; pinnae in 40–60 pairs, asymmetrical, 3–6 by 0.5–1 mm, apex acute, mucro less than 0.5 mm long, margins sparsely ciliate, base truncate; petiole 2–3 mm long with 1 adaxial gland (c. 0.5 mm in diam.); stipules 3–5 mm long. *Raceme* 1–3-flowered; bracts and bracteoles like stipules but smaller. *Flowers*: sepals ovate to long acute, 8–10 by 2–5 mm; petals orbicular to obovate, 9–13 by 8–10 mm; filaments 1–2 mm long, anthers straight to slightly curved, 4–8 mm long, 2 adaxial ones turning reddish; ovary 6–9 by 1 mm, sessile; style 3–4 mm long, glabrous; stigma flat, ciliate. *Legume*

green turning brown, strap–shaped, 4–6 by 0.5 cm. *Seeds* dark brown, oblong, flat, c. 2.5 by 1.5 mm.

Distribution — Singapore: fairly common; Old Upper Thomson Road, Pulau Tekong, Yishun Ave 6. Regarded as introduced in the Malesian area and Africa; common all over tropical Asia (Larsen and Hou, 1996a).

Ecology — A short-lived weed of 1–2 years found in waste- or reclaimed land and which flowers and fruits year-round. The leaves are more sensitive than those of *C. leschenaultiana* and are thigmonastic and photoblastic, folding up during the hottest hours of the day and at night. The Singapore specimens have been observed to have root nodules. In Malesia this is a polymorphic species with many ecotypes (Larsen and Hou, 1996a).

Uses — As green manure; the roots are used for spasms in the stomach and tea is made from the leaves by the Japanese (Burkill, 1935).

Notes — Like *C. leschenaultiana*, a line of hairs can be observed on the inner surface of the stipules near the point of insertion (Fig. 4b, inset).

Cynometra L.

Sp. pl. (1753) 382, Gen. pl. ed. 5 (1754) 179; Meeuwen, Blumea 18 (1970) 1–52; Cowan & Polhill in Polhill & Raven (eds.), Adv. Leg. Syst. 1 (1981)124; Watson & Dallwitz, Gen. Leg. — Caesalpinioideae (1983) 22.

Trees to 26 m tall; vegetative buds small, scaly. *Leaves* when new in bright pink tassles, when mature, paripinnate, 1–2-jugate; pinnae opposite, asymmetrical, chartaceous with an acroscopic midrib, glabrous; stipules early caducous. *Raceme* sessile, 1(–2) per axil or when cauliflorous, in groups of 3–5, densely-flowered, ± spherical in outline; rachis short, pubescent to glabrous. *Flowers* bisexual, zygomorphic; bracts scale-like, apressed hairy, lower ones reniform, decreasing in width up the raceme and becoming acute; bracteoles obovate, ciliate, caducous; sepals 4(–5), reflexed at anthesis, imbricate; petals 5(–4), narrow, glabrous; stamens 10 (-11), ± equal, filaments glabrous, anthers sagittate basally and apiculate at the apex, connective introrse, medi-dorsifixed, often cleft below the insertion of the filament, longitudinally dehiscent; ovary with 1(–2) ovules, densely pilose, shortly stipitate; style sparsely puberulous to halfway; receptacle shortly campanulate, circumscissle under the ripening fruit. *Fruit* indehiscent, rugose, brown scurfy, patently hairy, woody on a thickened

pedicel. *Seeds* 1(–2) per legume.

Distribution — About 70 spp., pantropical, in the West Pacific found eastwards as far as Micronesia, the Solomons and Fiji. and 14 spp. (13 indigenous and one cultivated) occurring in Malesia (Hou, 1996b). In Singapore there is only one indigenous sp.

Ecology — Mainly confined to the back-mangrove but also found inland.

Uses — As commercial timber (as the medium hardwood *kekatong* as classified by the Malaysian Timber Board). See under spp. *Cynometra cauliflora* L. (*nam nam*) is a cultivated sp. which was commonly planted for its fruits which can be eaten raw or cooked.

1. *C. ramiflora* L. var. *ramiflora*

Sp. pl. (1753) 382; Backer & Bakh. *f.*, Fl. Java 1 (1964) 526; Meeuwen, Blumea 18 (1970) 23; Whitmore, Tree fl. Malaya 1 (1972) 254; H. Keng, Gdns' Bull. Singapore 27 (1974) 259; Corner, Ways. Trees, 3rd ed. (1988) 434; H. Keng, Concise. Fl. Singapore (1990) 34; I.M. Turner, K.S. Chua & H.T.W. Tan, J. Singapore natn. Acad. Sci. 18 & 19 (1990) 72; I.M. Turner, Gdns' Bull., Singapore 45 (1993) 119; I.M. Turner, Gdns' Bull., Singapore 47 (1995) 299.

Cynometra ramiflora subsp. *bijuga* Prain

Trees 4–26 m tall. *Leaves* 1–2-jugate; pinnae oblong, elliptic, obovate–lanceolate, base cuneate, lower pair much smaller, 1.1–5.5 by 0.5–2.6 cm with an acute apex, upper pair 4.5–14 by 1.6–5.6 cm with an acute to acuminate apex, petiolules indistinct; rachis 0.8–1.3 cm, canaliculate; petiole 3–15 mm, canaliculate. *Raceme*: rachis 13–25 mm long. *Flowers*: bracteoles 3–4 mm long; sepals lanceolate, 3–6 by 1–1.5 mm long, ciliate marginally and apically to glabrous; petals lanceolate to spathulate, 3–8 mm long, sometimes shortly mucronate; filaments 4–7 mm long, anthers orbicular, 0.5–1 mm long; ovary slightly excentrically inserted, rhomboid, flattened, 1–2 by 0.5–1 mm; style 3.5–5.5 mm long; gynophore 0.5–1 mm long; hypanthium 1–1.25 mm deep; pedicel 7–15 mm long. *Fruit* ovate or elliptic, the tip pointing up, 2.3–3.8 by 1.5–3 cm. *Seeds* c. 1.2 by 1 cm.

Distribution — Singapore: now probably extinct; previously collected in Kranji and Sungei Jurong. From India throughout South-east Asia and Malesia to the Pacific but not in Sri Lanka and Australia (Hou, 1996b).

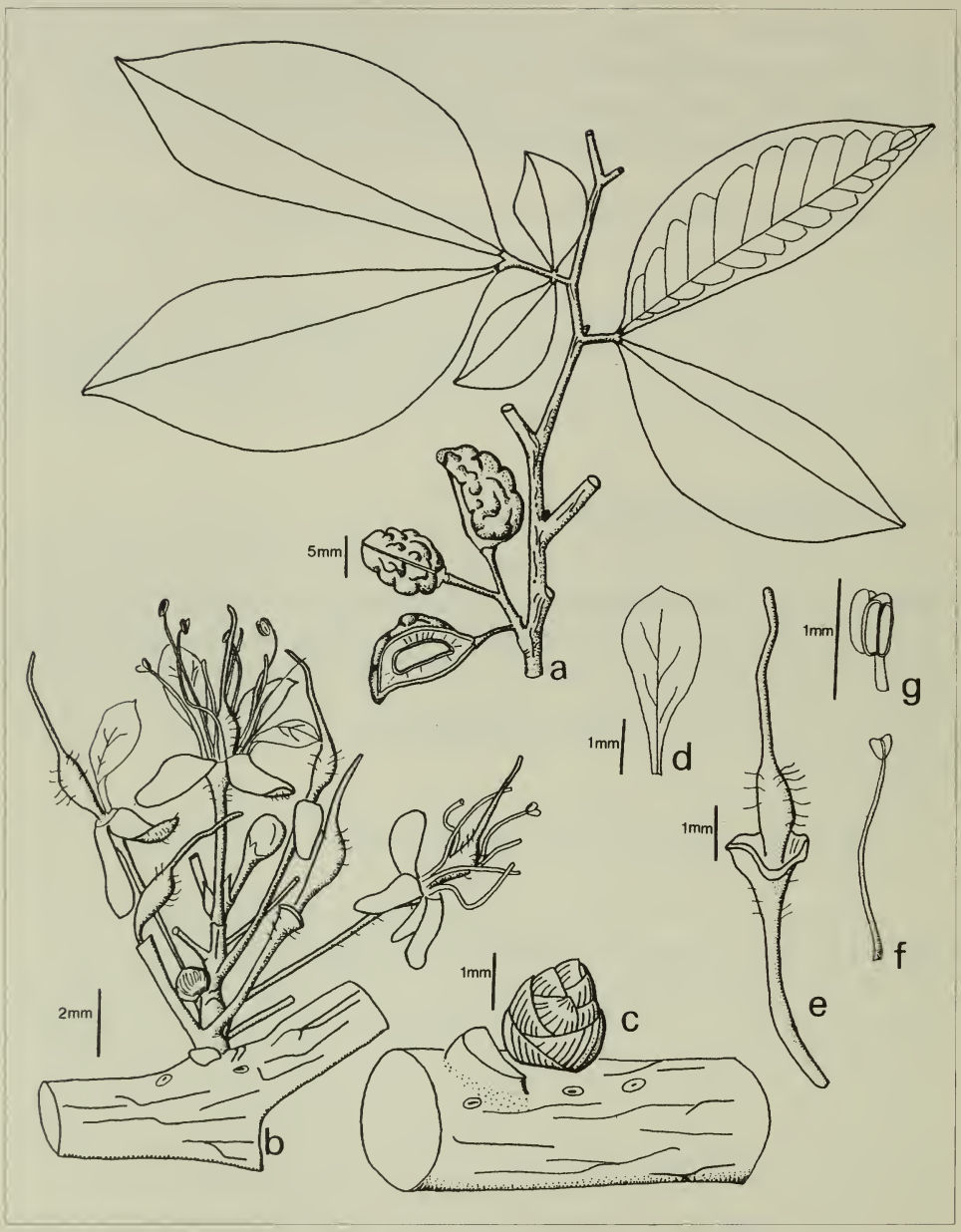

Figure 5. ***Cynometra ramiflora*** **L. var.** ***ramiflora*** a. Fruiting branch with one fruit longitudinally halved. (J. Sinclair SF 40957); b. Inflorescence; c. Scaly axillary bud; d. Isolated petal; e. Isolated carpel on hypanthium and pedicel; f. Back view of a stamen with cleft introrsed anther; g. Front view of an uncleft anther and top portion of filament. (Balara 3662).

Ecology — A constituent of the back-mangrove. The corky pericarp contains many air pockets which give buoyancy to the fruit which is dispersed by water (Meeuwen, 1970).

Uses — The hard, dark brown timber is only available in small quantities and is used for making doorposts; the roots purge and the leaves and oil from the seeds are used to treat skin diseases (Burkill, 1935).

Notes — The other var., var. *bifoliata* (Merr.) Meeuwen, has distinct petiolules 5–8 mm long but is only found in the Philippines (Luzon, Mindanao) (Meeuwen, 1970).

Dialium L.

Mant. 1 (1767) 3; Irwin & Barneby in Polhill & Raven (eds.), Adv. Leg. Syst. 1 (1981) 101; K. Larsen, S. S. Larsen & J. E. Vidal, Fl. Thailand 4:1 (1984) 85; J. P. Rojo, Fl. Males. 1:12 (1996) 608.

Trees; young stems lenticellate, pubescent. *Leaves* imparipinnate, rachis and petiole pubescent to glabrous, eglandular; pinnae alternate to subopposite, glabrous above, glabrous to pubsecent below, lamina margins entire, petiolules short, 2–6 mm long; stipules small, 1–1.5 mm wide, caducous. *Panicle* terminal, bractless, pubescent, lower branches usually subtended by leaves. *Flowers* bisexual, zygomorphic, small; sepals 5, reflexed at maturity, pubescent all over but minutely so inside; petals 0; stamens 2, filaments slender to stout, anthers basifixed, longitudinally dehiscent, connective puberulous; ovary sessile, centrally or excentrically inserted, subglobose, densely pubescent, ovules 1(–2); style short, straight to sharply curved; stigma small, slightly swollen; hypanthium flat or concave; pedicels pubescent. *Drupe* subglobose to obovoid, ± compressed, hairy or velvety, 1(–2)-seeded, exocarp crustaceous, endocarp pulpy, enveloping the seeds. *Seeds* 1(–2) per drupe, squarish, roundish or reniform, flat, smooth, longitudinally striate.

Distribution — Pantropical genus of 27 spp., not in Australia and the Pacific Islands (Rojo, 1996). In Malesia absent from the islands east of Borneo and Java. In Singapore there are two indigenous spp., one with two vars.

Ecology — In primary and late secondary forests.

Uses — The heartwood gives a good general-purpose timber, known

as *keranji* (Rojo & Alonzo, 1993). The pulpy endocarp of the fruits are edible but of slight economic importance (Rojo, 1996).

Notes — For the Singapore spp., *D. patens* has been reduced to *D. indum* var. *indum* and *D. maingayi* reduced to *D. platysepalum*, respectively following a revision by J. P. Rojo (unpubl. thesis, 1982). The spp. of *Dialium* are best separated with floral characters, in particular, the anthers (v-channeled or not), the depth of the hypanthium and the insertion of the ovary and stamens (centrally or excentrically).

Key to the Species

1a. Flower buds triulate, dark rusty pubescent; anthers v-channeled, triangular; filaments stout and flattened; style sharply recurved at the top; receptacle concave and wide; ovary and stamens excentrically inserted. Lamina of pinna chartaceous to thinly coriaceous, veins indistinct and not clearly raised on both surfaces, sometimes obscured by a golden indumentum below. Drupe velvety ..... **2. *D. platysepalum***

1b. Flower buds elliptic or rarely, ovate, white or whitish pubescent; anthers not v-channelled, oblong; filaments narrow and subulate; style straight to slightly recurved at the top; receptacle shallow and narrow, ovary and stamens ± centrally inserted. Lamina of pinna subcoriaceous to stiffly coriaceous, veins and reticulations distinct and slightly to prominently raised on both surfaces, not obscured by a golden indumentum on the lower surface at all times. Drupe hairy but not velvety ..... **1. *D. indum***

1. *D. indum* L.

Mant. 1 (1767) 24; Baker in J.D. Hook., Fl. Brit. India 2 (1878) 269, 270; Ridl., J. Straits Brch R. Asiat. Soc. 33 (1990) 74; Ridl., Fl. Malay Penins. 1 (1922) 622; de Wit, Blumea 7 (1953) 320, 321; Whitmore, Tree Fl. Malaya 1 (1972) 260; H. Keng, Gdns' Bull., Singapore 27 (1974) 260; K. Larsen, S.S. Larsen & J.E. Vidal, Fl. Thailand 4:1 (1984) 87; H. Keng, Concise Fl. Singapore (1990) 35; I.M. Turner, K.S. Chua & H.T.W. Tan, J. Singapore natn. Acad. Sci. 18 & 19 (1990) 72; I. M. Turner, Gdns' Bull., Singapore 45 (1993) 121; I.M. Turner, Gdns' Bull., Singapore 47 (1995) 302; J. P. Rojo, Fl. Males. 1:12 (1996) 609–612.

Dialium laurinum Baker
Dialium marginatum de Wit
Dialium patens Baker

Trees to 40 m tall; dbh to 1 m, twigs grey to dark brown pubescent. *Leaves*: petiole and rachis (4–)10–15(–20) cm long; pinnae 5, 7 or 9, lamina surfaces concolourous to darker above, ovate-oblong, ovate-lanceolate to broadly elliptic, (4–)6–10(–17) by (2.5–)3–5(–7.5) cm, veins in 8–10(–14) pairs, puberulous to glabrous below, apex rounded to long acute, base cuneate to obtuse, petiolules 3–6 mm. *Panicle* rachis 6–20 cm long. *Flowers*: sepals elliptic or ovate-elliptic, to 5 by 2.5 mm, white pubescent outside; filaments 0.5–2 mm long, anthers 2.5–4 by 1.5 mm; ovary to 2 mm long, white to golden-brown pubescent; style to 2 mm long; pedicels 2–6 mm long. *Drupe* brown, globose to ovoid, 1.5–2.5 by 1–1.5 cm, exocarp brittle. *Seeds* 1(–2) per drupe, brown, squarish to reniform, 7–12 by 5 mm.

Distribution — Singapore: rare; confined mainly to the Nature Reserves; previously collected in Kranji, MacRitchie Reservoir (South) and Mandai Road. Southernmost Thailand and in Malesia: Sumatra, Peninsular Malaysia, Borneo, Java (Rojo, 1996).

Ecology — Primary and late secondary forest.

Notes — There are two vars. that can be distinguished fairly accurately based on their pinnae. There are, however, intermediates. The type specimen of *Dialium laurinum* (Lectotype: *Maingay 1625* (residing in K), Peninsular Malaysia) is intermediate between the two vars. Ridley believed that the Singapore district, Kranji may have taken its name from this sp. which was previously abundant there (Keng, 1990). *Dialium indum* var. *indum* was not included in Singapore for its distribution area by Rojo (1996) in his revision of the Malesian spp. of *Dialium*. However *D. patens* which was sunk into this var., was already included in the flora of Singapore (Turner *et al.*, 1990; Turner, 1993) and collections made in Singapore were found in SING (specimen Corner 37721; J. Sinclair, SF 40957).

Key to Varieties

1a. Pinnae broadly elliptic to broadly lanceolate, stiffly coriaceous, apex obtuse to abruptly acuminate; veins and reticulations prominently raised above and below ..... var. ***bursa***

1b. Pinnae ovate-oblong to ovate-lanceolate, subcoriaceous, apex long acuminate to shortly cuspidate; veins and reticulations distinct but only slightly raised below ..... var. ***indum***

2. *D. platysepalum* Baker

In J.D. Hook. Fl. Brit. India 2 (1878) 270; Prain, J. Asiat. Soc. Beng. 66, ii (1897) 173, 174; Ridl., J. Straits Brch R. Asiat. Soc. 33 (1990) 74; Ridl., Fl. Malay Penins. 1 (1922) 622, 623; Whitmore, Tree fl. Malaya 1 (1972) 259–261; H. Keng, Gdns' Bull., (1974) 260, 261; K. Larsen, S.S. Larsen & J.E. Vidal, Fl. Thailand 4:1 (1984) 88; H. Keng, Concise Fl. Singapore (1990) 35; I.M. Turner, K.S. Chua & H.T.W. Tan, J. Singapore natn. Acad. Sci. 18 & 19 (1990) 72; I. M. Turner, Gdns' Bull., Singapore 45 (1993) 121; I.M. Turner, Gdns' Bull., Singapore 47 (1995) 302; J. P. Rojo, Fl. Males. 1:12 (1996) 612.

Dialium kingii Prain
Dialium maingayi Baker
Dialium wallichii (Baker) Prain

Trees to 45 m tall; dbh 90–120 cm; twigs greyish to rusty brown pubescent. *Leaves*: petiole and rachis (5–)10–18(–28) cm long; pinnae less the terminal one, in (5–)7–9(–13) pairs, lanceolate to oblong-elliptic, (4–)6–10(–15) by (1.5–)2–4(–7) cm, veins in 10–12(–15) pairs, lamina upper surface grey to dark brown when dry, lower surface milky brown or golden pubescent, puberulous to glabrescent or with a golden indumentum below, apex abruptly or long acuminate to cuspidate, base rounded to cuneate, petiolule 2–6 mm long. *Panicle* rachis 7–18 cm long, dark brown pubescent. *Flowers*: sepals ovate-triangular, to 6 by 4 mm, rusty to golden brown pubescent outside; style to 3 mm long; pedicel 2–4 mm long. *Drupe* dark brown, subglobose to obovoid, 1.5–3 long, sometimes with stipe to 2 mm long, pericarp firm. *Seeds* 1(–2) per drupe, brown, subglobose, 0.3–1.7 by 0.9–1 cm.

Distribution — Singapore: rare; Bukit Timah Nature Reserve (Jungle Falls); previously collected in Botanic Gardens' Jungle; Bukit Timah Nature Reserve (Rock Path and Ginger Walk), Jurong (Kim Teck Road), MacRitchie Nature Reserve (South). Malesia: Peninsular Malaysia, Sumatra, Borneo (Rojo, 1996).

Ecology — In primary forests and late secondary forest. In Malesia, also occurring in freshwater swamp forest. Flowers year-round, with peaks in Dececember to March and May to September, and fruiting most in July to October (Rojo, 1996).

Uses — As timber (*keranji*); pulpy endocarp of the fruits is edible (Burkill, 1935).

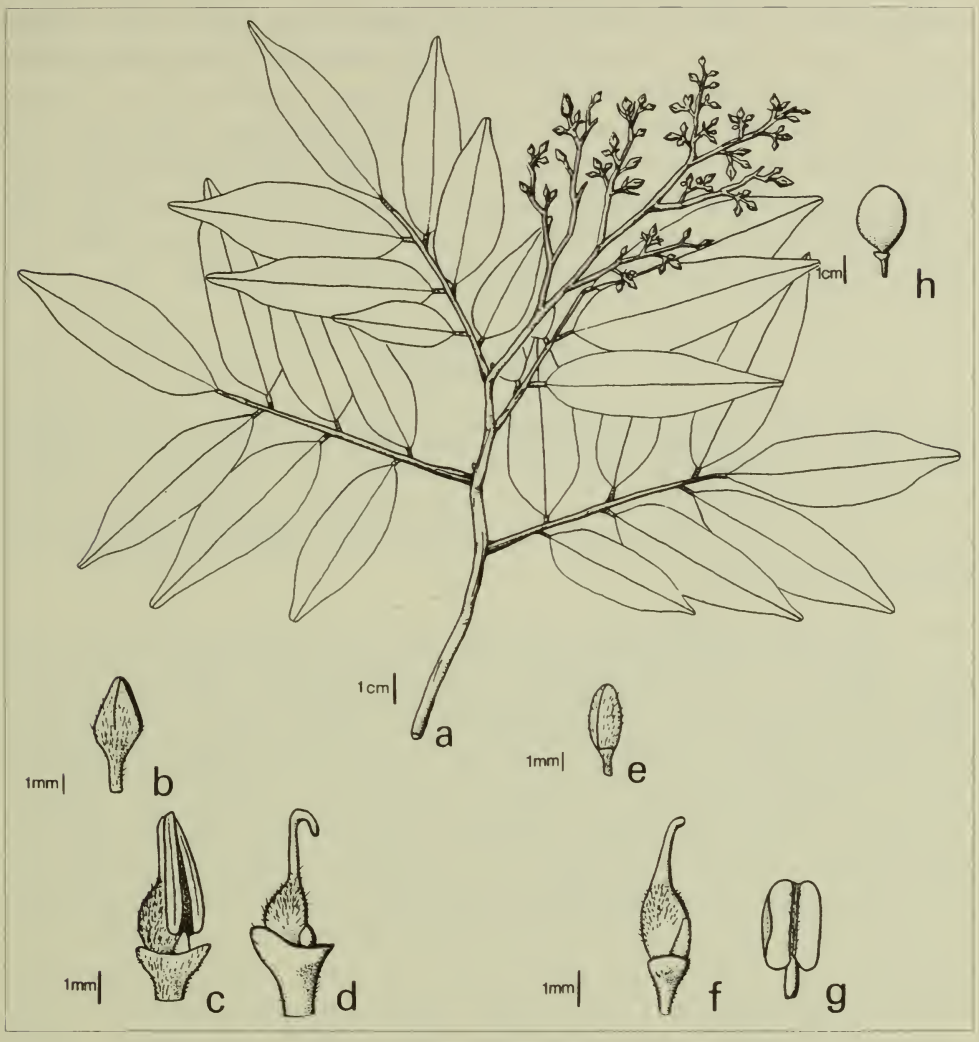

Figure 6. ***Dialium platysepalum*** **Baker.** a. Flowering branch; b. Triulate flower bud; c. Position of a v-channelled stamen; d. Isolated carpel on hypanthium and tip of pedicel (Ngadiman 3621); h. Drupe. (H. Keng S.N.) – *Dialium indum* L. e. (Ovate)-elliptic flower bud; f. Isolated carpel on hypanthium and tip of pedicel; g. Isolated stamen. (Kostermans 6562).

Notes — Based on the classification of Rojo (1996) there are 3 discrete 'groups' that can be distinguished in Singapore based on the size of the pinnae and colour and quality of their indumentum on their undersurface. The '*wallichii*' group is the most distinct group and is characterised in having lanceolate pinnae not exceeding 7 by 2 cm; the lower surface is also covered with a golden indumentum that often obscures the veins below and the upper surface is often greyish. The '*maingayi*' and '*platysepalum*' group are more difficult to separate; the '*maingayi*' group having a whitish to slightly golden indumentum below with indistinct veins and the '*platysepalum*' group having pinnae that are often tinged golden beneath. These 'groups' along with the '*kingii*' and '*triste*' groups are not given any nomenclatural or taxonomic status as the differences between them are slight and they form a gradient with intermediate specimens.

Intsia Thouars

Gen. Nov. Madg. (1806) 22; de Wit, Bull. Jard. bot. Buitenz.. 3:17 (1941) 139; Cowan & Polhill in Polhill & Raven (eds.) Adv. Leg Syst. 1 (1981) 128; Watson & Dallwitz, Gen. Leg. – Caesalpinioideae (1983) 35; K. Larsen, S.S. Larsen & J.E. Vidal, Flora of Thailand 4:1 (1984) 124; Ding Hou, Blumea 38 (1994) 322.

Trees often buttressed; trunk sometimes crooked, bark in brown and grey patches. *Leaves* paripinnate, (1–)2(–3)-jugate, laminas ovate to suborbiculate, chartaceous to subcoriaceous, usually with 1–2 small (≤ 0.5 mm across) crateriform glands at the base on the lower surface, petiolules twisted; stipules intrapetiolar, connate. *Inflorescence* a fascicle or a raceme of racemes, terminal or axillary, pubescent to glabrescent. *Flowers* bisexual, zygomorphic; bracts early caducous; calyx lobes 4, subequal, pubescent; petals: only one fully developed, limb flabellate, lower half narrowed into a claw, others rudimentary or absent; stamens 3(–4), staminodes 4–7, filaments and staminodes connate at the base, anthers dorsifixed, longitudinally dehiscent; ovary stipitate, stipe pubescent and adnate to the hypanthium except at the apical part; style coiled and slender; stigma capitulate, small. *Legumes* oblong, straight to slightly falcate, flattened, glabrous, valves leathery to slightly woody. *Seeds* 3–6 per legume, oblong, ovoid or discoid, flattened, scurfy.

Distribution — Two or more spp. from Madagascar, islands of the Indian Ocean, Tropical Asia, through Malesia to Northern Australia, Melanesia and Micronesia (Hou, 1994). In Malesia two spp. occur. In Singapore only one sp. is indigenous.

Ecology — *Intsia* spp. are long-lived spp. and are confined mainly to the coastal habitats, near mangroves and on sandy beaches (Hou, 1994).

Uses — As timber under the trade name *merbau*; *Intsia* timber is hard, very strong and durable and also termite-resistant; it has a wide range of uses both in- and outdoors from heavy construction to flooring, doors, posts, poles, and sleepers (Hou, 1994).

1. *I. bijuga* (Colebr.) Kuntze

Rev. Gen. pl. 1 (1891) 192; Ridl., J. Straits Brch R. Asiat. Soc. 33 (1900) 75; Ridl., Fl. Malay Penins. 1 (1922) 639; Whitmore, Tree fl. Malaya 1 (1972) 262; H. Keng, Gdns' Bull., Singapore 27 (1974) 262; K. Larsen, S. S. Larsen & J. E. Vidal, Flora of Thailand 4:1 (1984) 125; Corner, Ways. Trees, 3rd ed. (1988) 438; H. Keng, Concise Fl. Singapore (1990) 36; I.M. Turner, K.S. Chua & H.T.W. Tan, J. Singapore natn. Acad. Sci. 18 & 19 (1990) 72; I.M. Turner, Gdns' Bull., Singapore 45 (1993) 122; Ding Hou, Blumea 38 (1994) 324, ; I.M. Turner, Gdns' Bull., Singapore 47 (1995) 304.

Afzelia bijuga A. Gray
Afzelia retusa Kurz

Trees to 40 m tall; dbh to 1 m but usually smaller. *Leaves*: rachis 1.5–3.5 cm long; pinnae laminas ovate to broadly elliptic or suborbiculate, (2–)4–15 by 1.5–8.5 cm, abaxial midrib pubescent in the lower half, apex broadly acuminate, retuse or rounded, base cuneate to obtuse, petiolules 2–7 mm long; petiole 2.5–5.5 cm long; stipules c. 1 by 1 mm. *Raceme* 5–10 cm long. *Flowers*: calyx lobes ovate to obovate, 1–1.2 by 0.6–0.8 cm; petal white turning pink, red or purple, limb 1.2–1.5 by 1.5 cm, claw c. 0.5 by 0.1 cm, puberulous adaxially; filaments red or purple, 3–3.5 cm long, puberulous basally, anthers 2–2.5 by 0.5–1 mm, staminodes to 10 mm long; ovary 4–7.5 by 1.5 mm; style red or purple, 3–4 cm long; stigma c. 1 mm long; hypanthium 5–12 by 2–3 mm; pedicel 5–15 mm. *Legume* green turning purple to black, 7.5–20 by 5–6 cm. *Seeds* black, c. 2 by 2.5 cm.

Distribution — Singapore: rare; Pulau Tekong Kechil, Sungei Buloh Nature Park, Western Catchment Area; previously found in Bukit Timah Nature Reserve, Changi, Kranji Nature Reserve, Lim Chu Kang (Sarimbun), Pulau Jong, Pulau Ubin, Seletar, Tuas. Madagascar, islands of the Indian ocean, Tropical Asia, through Malesia to Northern Australia, Melanesia and Micronesia (Hou, 1994).

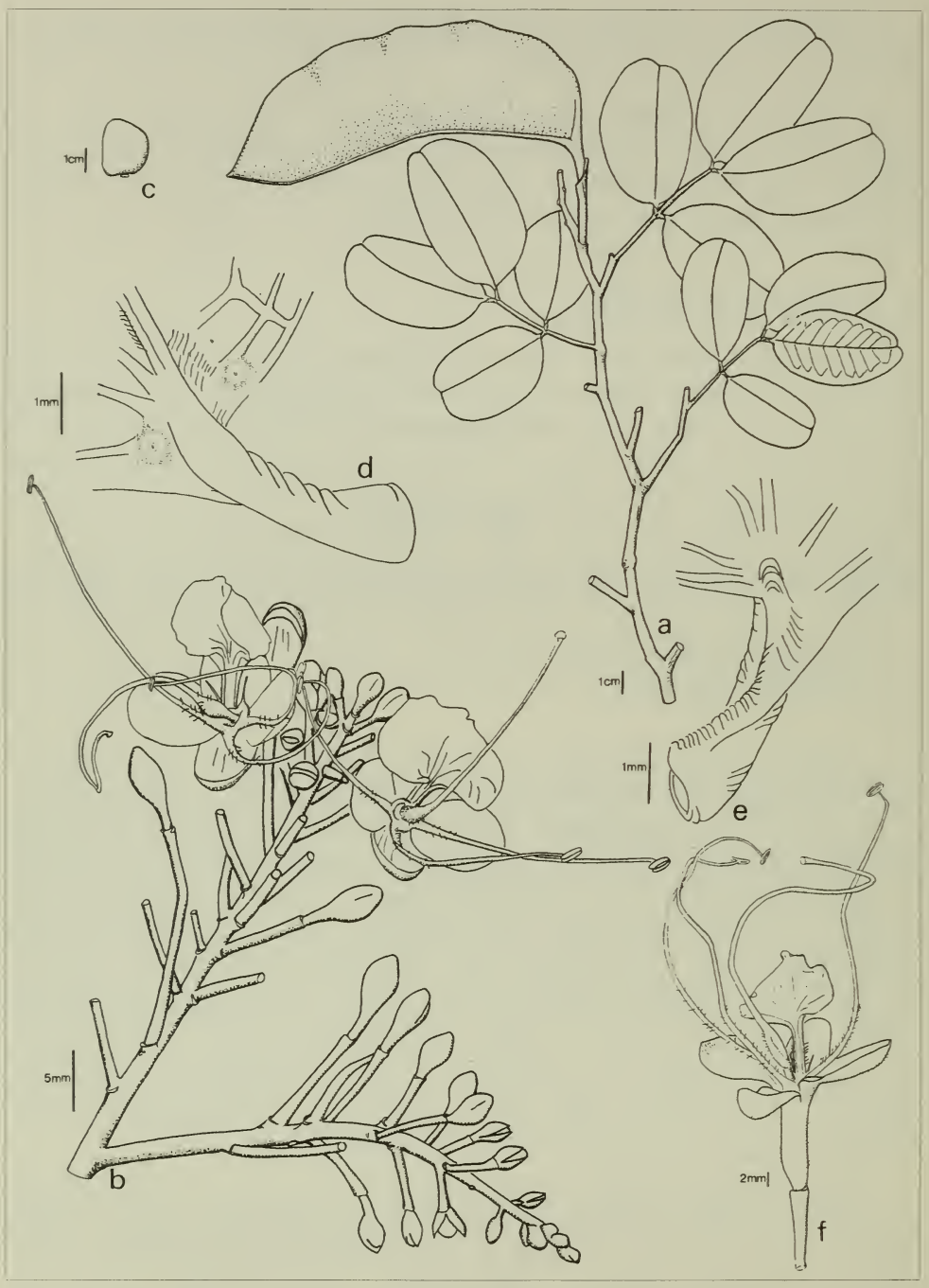

Figure 7. ***Intsia bijuga*** **(Colebr.) Kuntze.** a. Fruiting branch; b. Inflorescence; c. Seed; d. Lower surface of pinna showing crateriform glands (g); e. Adaxial view of twisted petiolule (A.H.B. Loo, A. Ibrahim, E.E.L. Seah & H.T.W. Tan A.Loo 037; f. Side view of a flower. (Rao & Jumali K6662).

Ecology — Along sea coasts, in beach forest or the back-mangrove, edges of rivers, in tidal or temporarily inundated places with (salty) water; also found in primary forests. A treelet c. 2 m tall growing from a rock crevice was observed to be in fruit in Pulau Tekong Kechil. The roots are reported to nodulate with a typical cowpea-type strain in Tully, Queensland, Australia (Allen and Allen 1981).

Uses — *I. bijuga* is a major tropical logwood and sawnwood sp. imported and exported under the trade name *merbau* (ITTO, 1996).

Koompassia Maingay ex Benth.

In Hooker's Icon. Pl. 12 (1873) 58, t. 1164; de Wit, Bull. Jard. bot. Buitenz. 3:17 (1947) 309; Irwin & Barneby in Polhill & Raven (eds.) Adv. Leg. Syst. 1 (1981) 101; Watson and Dallwitz, Gen. Leg. – Caesalpinioideae (1983) 37.

Trees, deciduous, gigantic; buttresses steep, thick and plank-like. *Leaves* imparipinnate; rachis and petiole ferruginous pubescent to glabrescent; pinnae alternate to subopposite, 5–14, laminas elliptic to ovate, subcoriaceous to coriaceous, pubescent below, midrib sunken and puberulous above, prominent below, lateral veins many, obscure on the upper surface, petiolules pubescent; stipules broadly ovate, small, early caducous. *Panicle* densely flowered, terminal or axillary, ferruginous pubescent. *Flowers* small; bracts and bracteoles lanceolate, small, caducous; calyx 5-lobed, lobes subequal, imbricate, pubescent outside; petals 5, subequal, with a prominent midvein, glabrous; stamens 5, alternating with the petals, filaments very short, glabrous, anthers basifixed, opening by apical and basal pores, both pores connected by a subdehiscent longitudinal rim; ovary sessile or sometimes, subsessile, 1-ovuled, pubescent; style very short; stigma indistinct; pedicels pubescent. *Samara* strongly compressed laterally, twisted 180°C at the base, pubescent, centre thickened and prominently veined, wing broad, circumferential, broadened apically, chartaceous. *Seed* 1 per legume, irregularly oblong, strongly compressed laterally.

Distribution — A small genus comprising three spp. in Malesia: Sumatra, Peninsular Malaysia, Borneo, Philippines and New Guinea (Hou, 1996c). In Singapore only one sp. is indigenous.

Ecology — In primary and late secondary forest; also in freshwater swamp forest.

Uses — All three spp. in Malesia have timber that are suitable for structural usage.

1. *K. malaccensis* Benth.

In Hooker's Icon. Pl. 3:2 (1876) 58, t. 1164; Ridl., J. Straits Brch R. Asiat. Soc. 33 (1900) 74; Merr. Phillip. J. Sc. Bot 10 (1915) 12; Ridl., Fl. Malay Penins. 1 (1922) 620; de Wit, Bull. Jard. bot. Buitenz. 3:17 (1947) 317; Whitmore, Tree fl. Malaya 1 (1972) 265; H. Keng, Gdns' Bull., Singapore 27 (1974) 262; K. Larsen, S. S. Larsen & J. E. Vidal, Flora of Thailand 4:1 (1984) 84; Corner, Ways. Trees, 3rd ed. (1988) 439; H. Keng, Concise Fl. Singapore (1990) 36; I.M. Turner, K.S. Chua & H.T.W. Tan, J. Singapore natn. Acad. Sci. 18 & 19 (1990) 72; I.M. Turner, Gdns' Bull., Singapore 45 (1993) 122; I.M. Turner, Gdns' Bull., Singapore 47 (1995) 304; Ding Hou, Fl. Males. 1:12 (1996) 634.

Trees to 45(–60) m tall; dbh 64(–120) cm; buttresses to 3(–6) m high. *Leaves*: rachis 6.2–19 cm long; pinnae 5–9(–14), laminas elliptic, ovate, oblong–ovate to elliptic-lanceolate, 3.5–10.4(–12.5) by 1.6–3.7 cm, finely areolate above, apex acuminate, slightly notched, base usually rounded, petiolules 4–9 mm long; petiole 1.4–3.9 cm long; stipules 2–2.5 mm wide. *Panicle* to 12 cm long. *Flowers*: bracts fleshy, c. 1 mm long, bracteoles subalternate, 0.5–1 mm long; calyx lobes ovate-lanceolate, 2–3 by 1 mm; petals orbicular to obovate, c. 2–3 by 1–1.5 mm, base fleshy; filaments abruptly broadened basally, 0.5–1 mm long; anthers heart-shaped, c. 1 by 0.5 mm; ovary c. 1 mm long; style < 0.5 mm long; pedicel 0.5–5 mm long. *Samara* green turning brown, oblong, 8.7–15 by 2.7–4.5 cm (including wing). *Seed* beige, to 3.5 by 1.5 cm, shallowly rugose.

Distribution — Singapore: vulnerable; Botanic Gardens' Jungle, the Nature Reserves; previously common all over Singapore (Keng, 1990). Malesia: Sumatra, Riau Archipelago, Bangka, Biliton, throughout Peninsular Malaysia, Borneo (Hou, 1996c).

Ecology — In primary and late secondary forest and freshwater swamp forest; sometimes occurring in groups near rivulets. Flowering and fruiting occurs year round. Seedlings can be found abundantly near the parent tree. Dispersal is by rapid spinning of the samaras sometimes to a distance of 50 m or more (Ridley, 1930). J. F. Maxwell (specimen J. F. Maxwell 81-225, in 1981), reported that the seeds were eaten by the long-tailed macaque, *Macaca fascicularis*, which bent the wings over the seed to expose it.

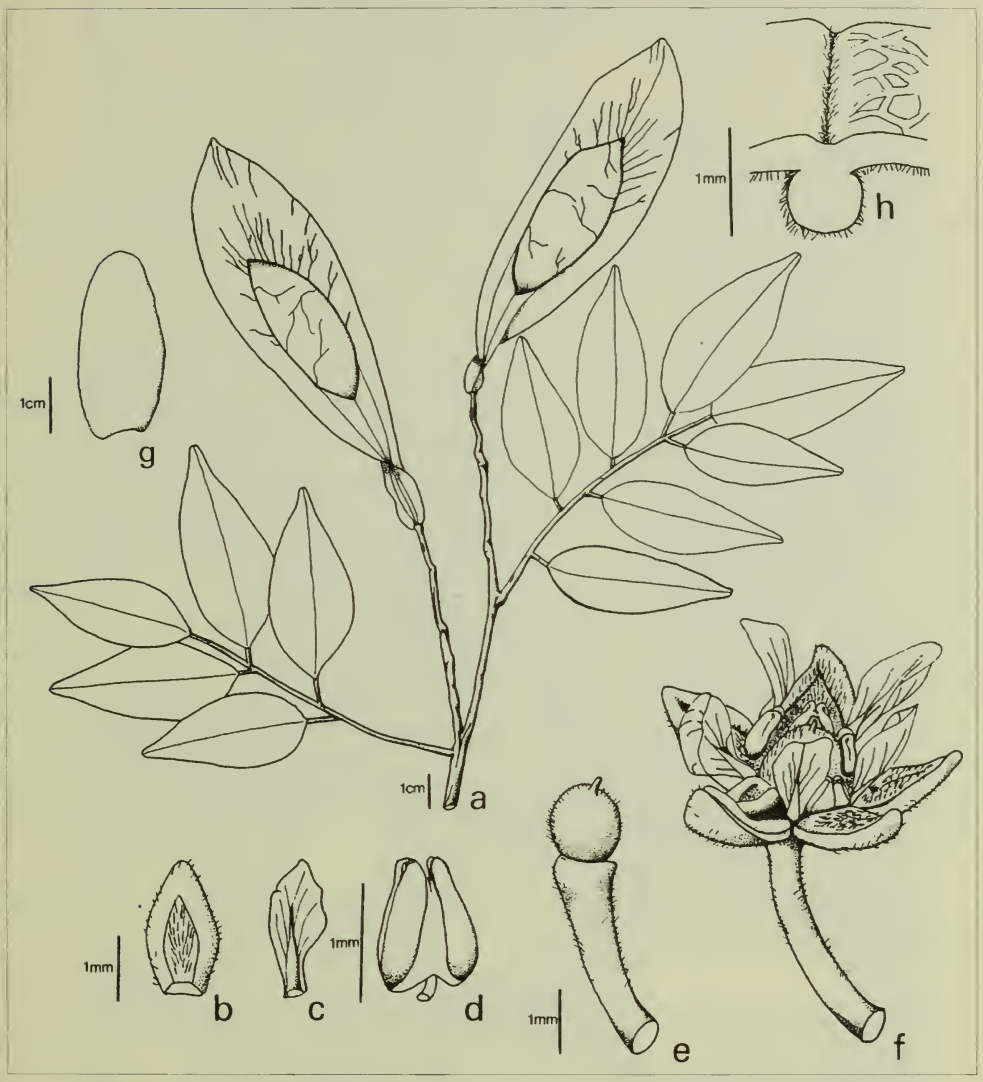

Figure 8. ***Koompassia malaccensis*** **Benth.** a. Fruiting branch (Kostermans 6682); b. Isolated sepal; c. Isolated petal; d. Isolated stamen; e. Isolated carpel on pedicel; f. Side view of a flower; g. Seed; h. Cross-section of pinnae showing pubescence on adaxial midrib and and abaxial surface of pinna. (J.F. Maxwell 81-225).

Uses — This sp. yields a coarse and hard, reddish heartwood which is known as *kempas*. The timber is strong but not popular as it is readily attacked by termites and has limited durability when exposed; it gives excellent charcoal and the buttresses are used as table tops (de Wit, 1947). *K. malaccensis* is a major tropical logwood and sawnwood sp. imported and exported under the trade name *kempas* (ITTO, 1996).

Peltophorum (Vogel) Benth.

J. Bot. 2 (1840) 75, *nom. cons.*;Vogel, Linnaea 11 (1837) 406; Taubert, PflFam. 3:3 (1892) 176; Polhill & J. E. Vidal in Polhill & Raven (eds.) Adv. Leg. Syst. 1 (1981) 90; Watson & Dallwitz, Gen. Leg. – Caesalpinioideae (1983) 47.

Deciduous trees, young shoots ferrugineous pubescent or glabrescent. *Leaves* twice-paripinnate; rachis and petiole ferruginous pubescent, grooved adaxially; pinnules numerous, opposite, small, venation finely reticulate, puberulous all over, sessile; stipules small, caducous. *Inflorescence* a raceme of racemes, terminal and axillary, ferrugineous pubescent. *Flowers* bisexual, zygomorphic; bracts minute, caducous; sepals 5, imbricate, reflexed, yellow-green, triangular, subequal, pubescent outside; petals 5, yellow, subequal, ferruginous woolly towards the short claw, venation finely reticulate; stamens 10, free, subequal, filaments slender, basally flattened and pilose, anthers brown, oblong, equal, dorsifixed and versatile, longitudinally dehiscent; ovary stipitate; style filiform, incurled; stigma broadly peltate; receptacle short, obscure. *Legume* indehiscent with a firm wing-like margin, oblong-lanceolate, strongly compressed laterally, woody, smooth, longitudinally striate, apex acute, base cuneate, slightly constricted between the seeds. *Seeds* lenticular to narrowly oblong, irregularly compressed.

Distribution — A pantropical genus of about 15 spp., three occurring in Malesia (Hou, 1996d). In Singapore, one sp. is indigenous.

Ecology — Coastal, along beaches and in the back-mangrove.

Uses — See under sp.

1. *P. pterocarpum* (DC.) K. Heyne

Nutt. Pl. Ned.–Ind., ed. 2 (1927) 755; DC., Prodr. 2 (1825) 441; Backer & Bakh. *f.*, Fl. Java 1 (1964) 547; Whitmore, Tree fl. Malaya 1 (1972) 268; H. Keng, Gdns' Bull. Singapore 27 (1974) 263; Hattink, Reinwardtia 9 (1974)

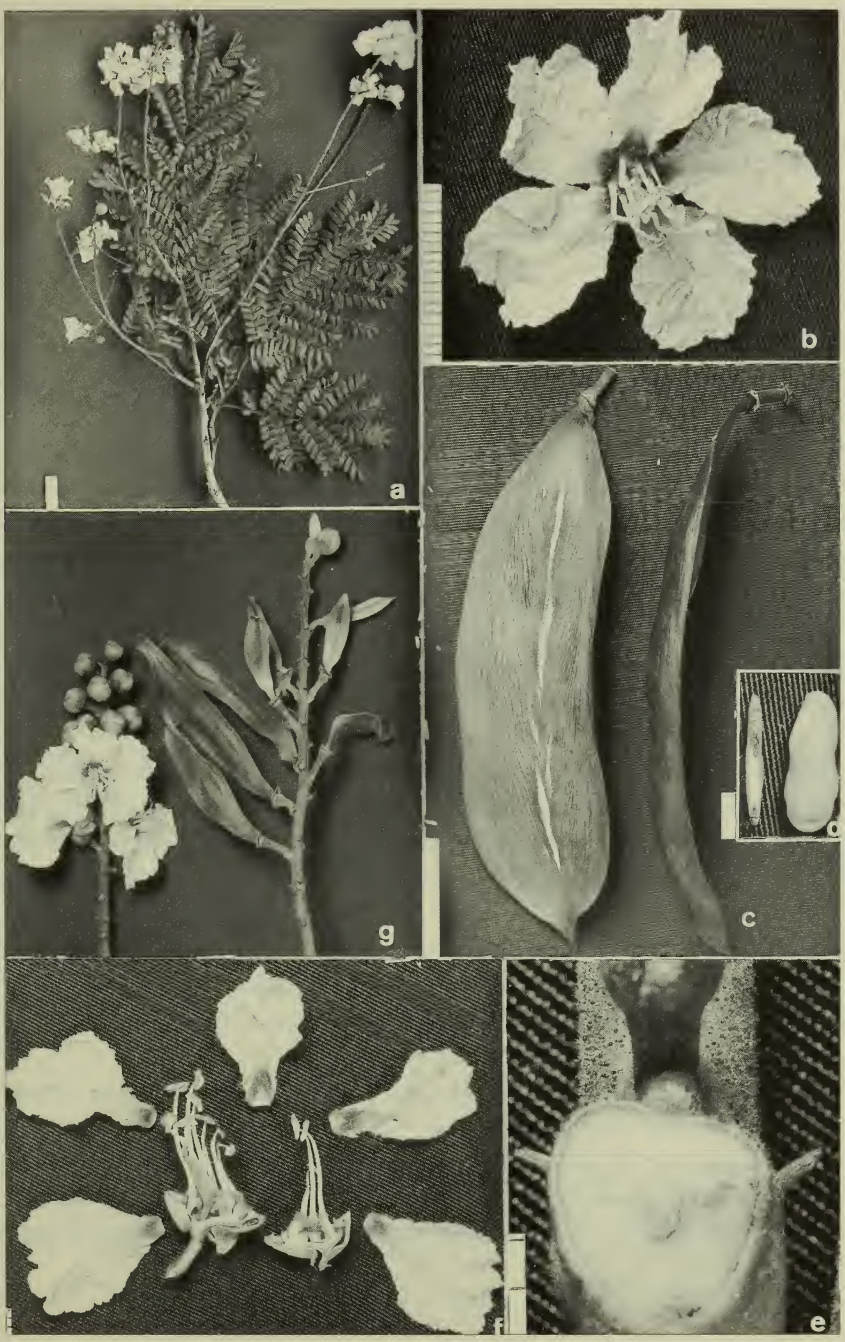

Figure 9. ***Peltophorum pterocarpum*** **(DC.) K. Heyne.** a. Flowering branch; b. Anterior view of flower; c. Side views of legume; d. Hilar view and side view of seed; e. Petiole cross-sectioned to show paired stipules (s); f. Exploded flower; g. Left - flowers and buds in a raceme, right - young legumes in a raceme. (Each interval on scale bar equivalent to 1mm). (A.H.B.Loo A.Loo 086).

59; Verdc., Manual New Guinea Legumes., Lae Bot. Bull. 11 (1979) 16; H. Keng, Concise Fl. Singapore (1990) 37; I.M. Turner, K.S. Chua & H.T.W. Tan, J. Singapore natn. Acad. Sci. 18 & 19 (1990) 73; I.M. Turner, Gdns' Bull., Singapore 45 (1993) 123; I.M. Turner, Gdns' Bull., Singapore 47 (1995) 308; Ding Hou, Fl. Males. 1:12 (1996) 651.

Peltophorum ferrugineum (Decne.) Benth.

Trees to 35 m tall; trunk beige, dbh 0.7–1.0 m. *Leaves*: rachis 9–14 cm long; pinnae in 4–13 pairs; pinnules in 15–18 pairs per pinna, oblong, 10–18 by 5–7 mm, puberulous all over, sessile, apex rounded to emarginate, base unequal, acute or rounded; petiole 2.5–4 cm long; stipules deltoid, 3–5 mm long. *Inflorescence* to 40 cm long. *Flowers* fragrant; bracts deltoid, c. 5 mm long; sepals 7–10 by 5 mm; topmost two sometimes puberulous in the upper median portion; petals obovate, 2–2.5 by 1.2–1.8 cm, wrinkled; filaments pale yellow, 10–13 mm long, anthers c. 2 by 1 mm; ovary densely pubescent, 5–7 by 1–2 mm; style c. 1 cm long, stigma white green, c. 2 by 2 mm, sticky; pedicel 5–7 mm. *Legume* reddish brown, 6–14 by 2–3.5 cm (including 4–5 mm wide wing-like margin). *Seeds* 1–3(–4) per legume, longitudinally arranged, beige, c. 12 by 5 mm.

Distribution — Singapore: almost extinct; possibly wild in Pulau Semakau and Pulau Tekong Kechil; previously collected in Changi (coast), Tuas. Sri Lanka, Thailand, Cambodia, South Vietnam; throughout Malesia to Northern Australia (Hou, 1996d).

Ecology — Coastal beach forest and the back-mangrove. Flowering and fruiting year round. Nodules are absent from this species (Allen & Allen, 1981). The flowers have a slightly sweet, musky scent.

Uses — Cultivated widely as a wayside and park tree in Singapore. The wood is strong and good for building, making boats and planks; in Java a dye from the bark is used to colour batik yellow-brown; the bark is used internally to cure dysentery and externally as a lotion for sprains, muscular aches, ulcers, as an eye-lotion, gargle and tooth-powder (Burkill, 1935).

Senna Mill.

Gdnr's. Dict., abr. ed. 4 (1754); Irwin and Barneby in Polhill and Raven (eds.), Adv. Leg. Syst. 1 (1981) 105; Mem. N. Y. bot. Gdn 35 (1982) 64;

Benth., Trans. Linn. Soc. Lond. 27 (1871) 513; de Wit, Webbia 11 (1956) 228; K. Larsen & Ding Hou, Fl. Males. 1:12 (1996) 673.

Cassia subg. *Senna* (Miller) Benth.

Herbs to shrubs, foetid or weakly so; stem glabrous to pubescent. *Leaves*: rachis and petiole eglandular or with 1(–2) glands adaxially, both grooved or widely and shallowly so, puberulous to pubescent, rachis abaxially produced to a short mucro beyond the uppermost petiolules; pinnae opposite, elliptic, oblong-elliptic, ovate or obovate, increasing in size distally, apex obtuse to acuminate, pubescent to glabrescent, base subequal, petiolules to 5 mm long; stipules paired. *Raceme* axillary and/or terminal. *Flowers* ebracteolate; sepals 5, ovate to orbicular, subequal; petals 5, obovate to orbicular, subequal, shortly clawed; stamens (6–)7, in 2 sizes, staminodes 0–3(–4), filaments straight, anthers basifixed, mostly beaked or produced, larger ones usually curved, opening by two apical pores, thecae not ciliate along the sutures. *Legume* indehiscent or inertly dehiscent through one or both sutures, in the latter case not coiling, transversly septate between seeds, many-seeded. *Seeds* and funicles variable.

Distribution — Pantropical genus of c. 260 spp., originating mainly from the Americas. There are 17 relatively common spp. in Malesia and of these probably only three spp. are indigenous (including *Senna tora*) (Larsen and Hou, 1996b). In Singapore, five exotic spp. are naturalized (Corlett, 1988).

Ecology — Mostly found in abandoned kampongs or farmland, occasionally in open places and along railway lines. Root nodules are absent.

Uses — See under spp.

Notes — See notes under *Chamaecrista* for reasons to recognize *Chamaecrista* and *Senna* as genera separate from *Cassia*

.

Key to the Species

1a. Shrubs; stem to 3–7 cm thick, marked with persistent stipules and conspicuous leaf scars. Petiole and rachis eglandular; rachis 30–56 cm long; pinnae in 8–20 pairs, margins orange, apex and base obtuse,

lowermost pair much smaller than the rest, recurved and set further apart from the rest (i.e., 1st internode the longest); stipules deltoid, stiff, persistent. Raceme densely 30–50-flowered. Bracts orange, petaloid, enveloping bud; sepals orange-yellow, incurled. Legume tetragonal, winged. Seeds olive-green, quadrangular ..... **1. *S. alata***

1b. Herbs or undershrubs; stem to 1.5 cm thick, not marked with persistent stipules or conspicuous leaf scars. Petiole or rachis with glands present; rachis 1.5–17 cm long; pinnae in 3–5(–7) pairs, margins green, apex rounded, acute or acuminate, base cuneate to rounded, lowermost pair not much smaller than the rest or recurved and not set further apart from the rest (i.e., all internodes subequal); stipules linear, membranous, caducous. Raceme loosely 2–5(–8)-flowered. Bracts green, linear, not enveloping bud; sepals green, flat or slightly incurved. Legume flattened or terete, wingless. Seeds brown, ovoid to orbicular 2

2a. Petiole base with glands; rachis eglandular, 5–17 cm long; pinnae in 3–5(–7) pairs, ovate or elliptic, apex acute or acuminate. Stigma subapical or lateral. Legume ± straight. Seeds dull 3

2b. Petiole eglandular; rachis with glands between the lowest pair or lowest two pairs of pinnae, 1.5–3 cm long; pinnae in 3 pairs, obovate, apex rounded or obtuse. Stigma apical. Legume falcate. Seeds glossy ... 4

3a. Plant foetid, pubescent all over. Pinnae pubescent on both surfaces; petiolar gland subulate, c. 1.5 mm long. Inflorescence a leafy raceme. Lowest part of the androecium a stamen with a narrow anther; ovary woolly. Legume hirsute, angular. Seeds obovoid, without an areole ..... **2. *S. hirsuta***

3b. Plant not foetid to slightly so, ± glabrous. Pinnae glabrous above, glabrescent below; petiolar gland globose, c. 3 mm across. Inflorescence in ± leafless raceme. Lowest part of the androecium a filamentous staminode with a petaloid anther; ovary shortly pubescent. Legume glabrous to glabrescent, sub-terete. Seeds orbicular, brown with a paler areole ..... **4. *S. occidentalis***

4a. A gland between the lowest pair of pinnae only. Pedicel of flower usually 1–3.5 cm long, of legume 2–4.5 cm long. 3 largest anthers bottle-necked below the apex. Areole of seed 0.3–0.5 mm wide, covering little of the seed surface. Plant weakly foetid ..... **3. *S. obtusifolia***

4b. A gland between the lowest 2 pairs of pinnae. Pedicel of flower usually 0.5–1 cm long, of legume 1–1.5 cm long. 3 largest anthers

abruptly rounded at the apex. Areole of seed 1.5–2 mm wide, covering much of the seed surface. Plant strongly foetid ..... **5. *S. tora***

1. *S. alata* (L.) Roxb

Fl. Ind. ed. 2, 2 (1832) 349; Sp. pl. (1753) 378; Ridl., J. Straits Brch R. Asiat. Soc. 33 (1900) 74; Ridl., Fl. Malay Penins. 1 (1922) 619; de Wit, Webbia 11 (1956) 231; H. Keng, Gdns' Bull., Singapore 27 (1974) 257; Irwin & Barneby, Mem. N. Y. bot. Gdn 35 (1982) 460; R.T. Corlett, J. Biogeog. 15 (1988) 657–663; Corner, Ways. Trees, 3rd ed. (1988) 429; J.B. Hacker, A guide to herbaceous and shrub legumes of Queensland (1990) 86; H. Keng, Concise Fl. Singapore (1990) 33; I.M. Turner, K.S. Chua & H.T.W. Tan, J. Singapore natn. Acad. Sci. 18 & 19 (1990) 72; I.M. Turner, Gdns' Bull., Singapore 45 (1993) 124; I.M. Turner, Gdns' Bull., Singapore 47 (1995) 309; K. Larsen & Ding Hou, Fl. Males. 1:12 (1996) 675.

Cassia alata L.

Shrubs, 1–2(–5) m tall. *Leaves*: rachis orange and widely grooved above; pinnae in 8–20 pairs, oblong-elliptic but distal pairs obovate, 5–15 by 3–8 cm , veins pubescent below, petiolules c. 5 mm long; petiole 2–3 cm long; stipules brownish-red. *Raceme* 25–80 by 4–6 cm. *Flowers*: bracts 2.5–3 by 1.5–2 cm; sepals obovate, 1.5–1.8 by 0.7–1 cm; petals clawed, limb ovate to oblong, rarely obovate, 1.8–2.5 by 1–1.6 cm (including 2–4 mm long claw); stamens 7, unequal, largest 2: filaments laterally compressed, 5–6 by 2 x 1 mm, anthers swollen, curved, 12–13 mm long, central 4: filaments and anthers 3–4 mm long, lowest one: filament 0.5–1 mm long, anther 4–5 mm long, staminodes 3; ovary green, falcate with grooved sides, 15–20 by 2 mm, minute pubescent, style c. 7 mm long, stigma small, pedicel 4–5 mm long. *Legume* green turning black, tetragonal, 10–15 by 1.5–2 cm (including 4–8 mm wide wings). *Seeds* c. 50, quadrangular, flat, 7–8 by 5–8 mm.

Distribution — Singapore: common in abandoned kampongs; Island Club Road, Rochester Park, Old Upper Thomson Road (end of Kallang River), Pulau Tekong (South), Sungei Mandai Kechil (Kampong Fatimah), Yishun Ave 6; previously collected in Ang Mo Kio and Choa Chu Kang. It is probably native in the rivers of the Guianas and periphery of the Orinoco and Amazon basins in Brazil, Colombia and Venezuela. It became fully established in Java by the middle of the 17th century (Irwin and Barneby, 1982).

Ecology — Found near riverbanks or margins of ponds and ditches in abandoned kampongs, often in groups or scattered. It may be branched or not, commonly procumbent, establishing itself over a small area by leaning and producing erect shoots. The leaves are thigmonastic and photonastic, turning up during the hottest and sunniest hours of the day, in rainy weather and in the evenings. The legumes rattle when shaken.

Uses — This species has been used as an effective remedy for ringworm and other cutaneous diseases (Burkill, 1935). The leaves are also taken internally as a laxative, astringent, expectorant, purgative taenifuge, tonic and mixed with lime juice as an anthelmintic, the flowers are taken internally as a tonic for skin diseases, the seeds are taken internally for skin diseases, the bark contains tanning material, the roots used in West Africa for tattooing or tribal markings and the leaves contain chrysophanic acid (2.2%) and are used as an antiparasitic (Duke, Reed & Weder, 1981a). Burkill (1935) also mentioned that the roots are used internally for constipation and externally for ringworm and that the toasted leaves along with beans of *Glycine max*, are sometimes made into a drink similar to coffee. The plant may poison stock, and is sometimes a weed in pastures as it may rapidly reduce the area available for grazing as livestock will not eat the plant (Verdcourt, 1979).

2. *S. hirsuta* (L.) Irwin & Barneby var. *hirsuta*

Phytologia 44 (1979) 499; Sp. pl. (1753) 378; Ridl., J. Straits Branch Asiat. Soc. 33 (1900) 74; Ridl., Fl. Malay Penins. 1 (1922) 618; de Wit, Webbia 11 (1955) 250, 251; M.R. Hend., Mal. Wild. Fl. Dic. (1959) 96; H. Keng, Gdns' Bull., Singapore 27 (1974) 258; Irwin & Barneby, Mem. N. Y. bot. Gdn 35 (1982) 434; R.T. Corlett, J. Biogeog. 15 (1988) 657–663; Randell, J. Adelaide Bot. Gard. 11 (1988) 42; H. Keng, Concise Fl. Singapore (1990) 33; I.M. Turner, K.S. Chua & H.T.W. Tan, J. Singapore natn. Acad. Sci. 18 & 19 (1990) 72; I.M. Turner, Gdns' Bull., Singapore 45 (1993) 124; I.M. Turner, Gdns' Bull., Singapore 47 (1995) 309; K. Larsen & Ding Hou, Fl. Males. 1:12 (1996) 679.

Cassia hirsuta L.

Herbs to 2 m tall; hirsute all over. *Leaves*: rachis 5–17 cm long; pinnae in 3–5(–7) pairs, laminas ovate-elliptic, 2–12 by 1–3.5 cm, apex acute to acuminate, petiolules c. 2 mm long; petiole 3–6 cm long; stipules 7–15 x 1 mm. *Raceme* 2–5(–8)-flowered. *Flowers*: bracts 3–5 mm long;

sepals unequal, outer 2: ovate, 3–7 by 3–4 mm, villose outside; inner 3: obovate, 7–10 by 4–6 mm; petals 9–17 by 7–11 mm (including 1–2 mm long claw), limb obovate to orbicular; stamens 7, largest 2: filaments winged, 4–6 mm long, anthers curved, 6 mm long, beaked; central 4: similar but half as long, lowest 1: as long as the largest; ovary ± falcate, 5–8 mm long; style 1.5–2.5 mm long; stigma subapical, ciliate; pedicel 1–2 cm long. *Legume* grey brown, ± straight, flattened, sides grooved, 10–14 by 0.3–0.5 cm, hirsute. *Seeds* 50–100 per legume, 2–3 by 1 mm.

Distribution — Singapore: rare; previously collected in Geylang, Pasir Panjang, Yio Chu Kang. Origin in tropical South America; long naturalized in the Old World wet tropics (Irwin and Barneby, 1982).

Ecology — Along roadsides, railways, in old kampongs or abandoned plantations and farmland.

Uses — This species is used as green manure and to treat herpes (Heyne, 1927). The leaves are eaten steamed (Ochse, 1931).

Notes — Two varieties, var. *puberula* and var. *hirsuta*, are recognized in the Malesian area (Larsen and Hou, 1996b); the former found only in the Phillipines, has arched legumes and in the revision of de Wit (1955) is synonymous with *Cassia leptocarpa* Benth. In the use of the keys given by Larsen and Hou (1996b) to distinguish the varieties, it is important to examine mature legumes as immature ones are ± arched as in var. *puberula*.

3. *S. obtusifolia* (L.) Irwin & Barneby

Mem. N. Y. bot. Gdn 35 (1982) 252; Sp. pl. (1753) 377; Ridl., J. Straits Branch Asiat. Soc. 33 (1900) 74; Ridl., Fl. Malay Penins. 1 (1922) 618; de Wit, Webbia 11 (1955) 254; Brenan, Kew Bull (1958) 248; H. Keng, Gdns' Bull., Singapore 27 (1974) 258; R.T. Corlett, J. Biogeog. 15 (1988) 657–663; Randell, J. Adelaide Bot. Gard. 11 (1988) 45; J.B. Hacker, A guide to herbaceous and shrub legumes of Queensland (1990) 96; H. Keng, Concise Fl. Singapore (1990) 33; I.M. Turner, K.S. Chua & H.T.W. Tan, J. Singapore natn. Acad. Sci. 18 & 19 (1990) 72; I.M. Turner, Gdns' Bull., Singapore 45 (1993) 124; Turner, Gdns' Bull., Singapore 47 (1995) 309; K. Larsen & Ding Hou, Fl. Males. 1:12 (1996) 681.

Cassia obtusifolia L.

Herbs or subshrubs to 2 m tall. *Leaves*: rachis 1.5–3 cm long, adaxial

gland c. 2 mm long; pinnae in 3 pairs, laminas obovate, 1.5–5 by 0.7–3 cm, increasing in size distally, membranous, pubescent below, base cuneate, petiolule 1–2 mm; petiole 1.5–3 cm; stipules linear, 5–20 by 0.5–1 mm, setaceous. *Raceme* 1–2(–3)-flowered on a c. 2 mm long peduncle. *Flowers*: bracts linear, c. 5 mm long; sepals ovate, subequal, 0.6–0.9 byx 0.3–0.5, puberulous; petals subequal, 0.7–2 by 0.4–1.2 cm (including 0.5–1.5 mm long claw), limb obovate; stamens 7, filaments 1–2 mm long, anthers unequal, largest 3: 4–5 mm long, central 4: 2.5–3.5 mm long, staminodes 0–3; ovary falcate, 7–13 by 0.5–1 mm, pubescent; style 2–3 mm long; stigma truncate, ciliate; pedicel pubescent. *Legume* brown, falcate, flattened, 11–23 by 0.5 cm, puberulous. *Seeds* 20–30(–50) per legume, brown, rhombic to ovoid, 3–5 by 2 by 2 mm, smooth.

Distribution — Singapore: uncommon; previously collected in Bukit Kallang and Tanglin. Probably native to the Americas and rare in Malesia (Larsen and Hou, 1996b).

Ecology — In old kampungs or abandoned plantations and farmland.

Uses — The leaves used as a vegetable, treatment for skin problems and as a cure for vomitting and stomach-ache while the roots are used for constipation (Burkill, 1935).

Notes — This species is closely related to *Senna tora* such that some authors regarded them as conspecific (e.g., Bentham, 1871). However, de Wit (1955) separated them into distinct taxa based mainly on foliar glands, pedicel length and scent. Brenan (1958) further distinguished the two species on differences in the width of the areoles of their seeds and emphasized the difference in the stamens.

4. *S. occidentalis* (L.) Link

Handb. 2 (1831) 140; Sp. pl. (1753) 377; Ridl., J. Straits Branch Asiat. Soc. 33 (1900) 74; Ridl., Fl. Malay Penins. 1 (1922) 618; de Wit, Webbia 11 (1955) 256; M.R. Hend., Mal. Wild. Fl. Dic. (1959) 99; H. Keng, Gdns' Bull. Singapore 27 (1974) 258; Irwin & Barneby, Mem. N. Y. bot. Gdn 35 (1982) 436; R.T. Corlett, J. Biogeog. 15 (1988) 657–663; Randell, J. Adelaide Bot. Gard. 11 (1988) 41; Hacker, A guide to herbaceous and shrub legumes of Queensland (1990) 97; H. Keng, Concise Fl. Singapore. (1990) 33; I.M. Turner, K.S. Chua & H.T.W. Tan, J. Singapore natn. Acad. Sci. 18 & 19 (1990) 72; I.M. Turner, Gdns' Bull. Singapore 45 (1993) 124; Turner, Gdns' Bull., Singapore 47 (1995) 309; K. Larsen & Ding Hou, Fl. Males.

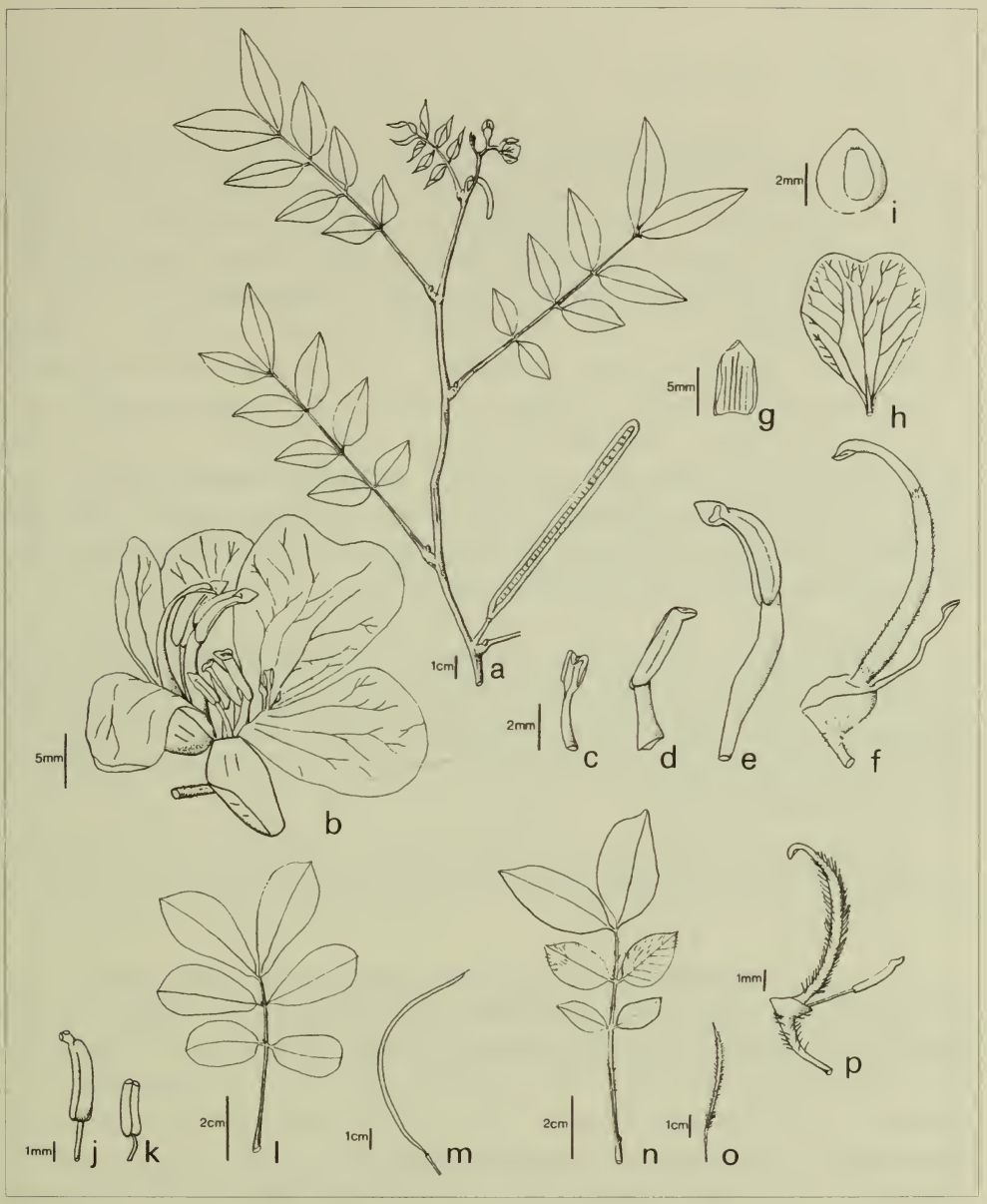

Figure 10. ***Senna occidentalis*** **(L.) Link.** a. Flowering and fruiting branch; b. Side view of flower; c. Isolated staminode; d. One of four middle stamens; e. One of three upper stamens; f. Isolated carpel on hypanthium with lowermost staminode attached on hypanthium and tip of pedicel; g. Isolated sepal; h. Isolated standard petal A.H.B. Loo, A.Loo 070); i. Seed. (Abu Kassim s.n.). ***Senna obtusifolia*** **(L.) Irwin & Barneby. j.** One of three largest stamens showing bottle-neck below apex. (R. W. Hullett S. N.). ***Senna tora*** **(L.) Roxb.** k. One of three largest stamens showing abruptly rounded apex; l. Leaf; m. Falcate legume. (P. W. Wong 2717). – ***Senna hirsuta*** **(L.) Irwin & Barneby var.** ***hirsuta.*** n. Leaf; o. Young legume; p. Isolated carpel with lowermost anther attached on hypanthium and pedicel. (Abu Kassim s.n.)

1:12 (1996) 681.

Cassia occidentalis L.

Herbs to subshrubs, 0.5–2 m tall. *Leaves*: rachis 7–10 cm long, with a puberulous groove; pinnae in 3–5(–6) pairs, laminas ovate-elliptic, 3–10.5 by 2–3.5 cm, petiolules 3–4 mm; petiole 3–6 cm long, gland glossy purple; stipules 3–20 by 2–3 mm. *Raceme* 2–4-flowered on a 2–5 mm long peduncle. *Flowers*: bracts 8 by 3–4 mm; sepals unequal, 2 ovate, 6–8 by 4–6 mm, 3 obovate to orbicular, 6–11 by 6–7 mm; petals unequal, 3 orbicular to widely obovate, 12–15 by 10–15 mm, 2 obovate, c. 12–17 by 7–9 mm, all excluding 1–2 mm long claw; stamens 6, largest 2: filaments 6–9 mm long, anthers 5–6 mm long, central 4: filaments 3–4 mm long, anthers 3–5 mm long, staminodes 4; ovary green, 1–2 cm long, pubescent; style 4–5 mm long; stigma lateral, ciliate; pedicel c. 1 cm long. *Legume* brown with pale margins, ± straight, 10–12 by 0.5–1 cm, glabrous to glabrescent. *Seeds* 30–50 per legume, flat, 3–4 mm in diam., smooth.

Distribution — Singapore: uncommon; East Coast Road, School of Biological Sciences Garden, the National University of Singapore; previously collected in Changi, Geylang and Jalan Bahar. This sp. is of South American origin and probably naturalized in the Malesian area (Larsen and Hou, 1996b).

Ecology — In old kampongs and abandoned farmland and plantations and along roads or near houses.

Uses — The seeds may be used as a substitute for coffee, the young leaves and legumes are eaten with rice usually as medicine, the leaves are used to cure headache and toothache and alcoholic infusions are slightly insecticidal (Burkill, 1935). The plant is used as green manure, as a purgative, febrifuge with diuretic and sudorific properties, the roots and leaves used as a substitute for quinine and the seeds and leaves used externally to treat skin diseases and as an antiperiodic, and the roots are used for snakebite and as an antidote for poisons (Duke, Reed & Weder, 1981b). In Senegal, the leaves are used to protect cowpea seeds (*Vigna unguiculata*) against *Callosobruchus maculatus* (Coleoptera: Bruchidae) (Liennard *et al.*, 1993).

5. *S. tora* (L.) Roxb.

Fl. Ind. ed. 2, 2 (1832) 340; Sp. pl. (1753) 376; Prain, J. As. Soc. Beng. 66, ii

(1897) 158, 475; Ridl., Fl. Malay Penins. 1 (1922) 618; de Wit, Webbia 11 (1955) 276; Brenan, Kew Bull (1958) 248; M.R. Hend., Mal. Wild. Fl. Dic. (1959) 99; H. Keng, Gdns' Bull., Singapore 27 (1974) 258; R.T. Corlett, J. Biogeog. 15 (1988) 657-663; Randell, J. Adelaide Bot. Gard. 11 (1988) 45; J.B. Hacker, A guide to herbaceous and shrub legumes of Queensland (1990) 102; H. Keng, Concise Fl. Singapore (1990) 33; I.M. Turner, K.S. Chua & H.T.W. Tan, J. Singapore natn. Acad. Sci. 18 & 19 (1990) 72; I.M. Turner, Gdns' Bull., Singapore 45 (1993) 124; I.M. Turner, Gdns' Bull., Singapore 47 (1995) 309; K. Larsen & Ding Hou, Fl. Males. 1:12 (1996) 689.

Cassia tora L.

Erect herbs to subshrubs up to 1.5 m tall; puberulous to pubescent all over. *Leaves*: rachis 1.5–2.5 cm long, glands c. 2 mm long; pinnae in 3 pairs, laminas obovate, 2–4.5 by 1–2.5 cm, membranous, pubescent below, apex rounded or obtuse, base cuneate to rounded, subequal, petiolule 2 mm long; petiole 1.5–4 cm long; stipules 5–11 by 1 mm. *Raceme* axillary, 2-flowered on a 2–5 mm long peduncle. *Flowers*: bracts 2–5 mm long; sepals ovate, subequal, 4–7 by 2–4 mm, puberulous below; petals obovate, unequal, 8–10 by 5–6 mm; stamens 7, filaments 2–3 mm long, anthers unequal: largest 3, c. 3 mm long, central 4: c. 1.5–2 mm long, staminodes 0–3; ovary green, falcate, c. 7 mm long, densely pubescent; style c. 2 mm long; stigma ciliate; pedicel pubescent. *Legume* light brown, falcate, flattened, 10–15.5 by 0.2–0.5 cm, puberulous. *Seeds* 20–30 per legume, glossy light brown, rhomboidal, 4–5 by 2.5 by 2 mm.

Distribution — Singapore: uncommon; previously found in Pulau Ubin, Tanglin. Its origin is uncertain but is strictly palaeotropic in occurrence. It is common throughout Malesia at lower altitudes (Larsen and Hou, 1996b).

Ecology — In old kampongs or abandoned plantations and farmland.

Uses — Its leaves are used as a purgative, cure for coughs and against ringworm, the young leaves are eaten as a vegetable, the seeds contain emodin and are applied for itching, used for boils and as an internal and external medicine for eye diseases and the seeds are also used as a substitute for coffee (Burkill, 1935).

Sindora Miq.

Fl. Ind. Bat. Suppl. (1861) 287; de Wit, Bull. Jard. bot. Buitenz.. 3:18 (1949) 5; Watson & Dallwitz, Gen. Leg. — Caesalpinioideae (1983) 53; Cowan & Polhill in Polhill & Raven (eds.) Adv. Leg. Syst. 1 (1981) 132.

Trees. *Leaves* paripinnate, 2–4-jugate; pinna laminas elliptic to obovate, coriaceous, rarely subcoriaceous, midrib slightly grooved above, secondary veins many, emerging at 60° or more from the midrib measured from the apex, anastomosing to a thickened marginal vein, tertiary veins finely reticulate, petiolules short; stipules foliaceous, caducous. *Panicle* axillary or terminal. *Flowers* bisexual, zygomorphic; bracts and bracteoles small, caducous; sepals narrowly overlapping, 4, spinescent or not, strigose inside, pubescent outside; petal 1, fleshy; androecium of 9 connate stamens and staminodes and 1 uppermost free staminode, the lower 9 filaments shortly, obliquely and basally connate into a hirsute sheath, the 2 uppermost ones of the 9 with elongated filaments and dorsifixed and longitudinally dehiscent anthers, the other 7 lower filaments shorter with or without small, imperfect anthers; ovary subsessile, 2–5-ovuled, pubescent; style filiform, recurved; stigma small; pedicel short, pubescent. *Legume* elliptic to orbicular, flat, woody, armed or not, dehiscent, beak curved. *Seeds* 1–3 per legume, black, shiny, each set on a large fleshy aril; cotyledons split, funicle curving.

Distribution — A genus of 18–20 spp. in West Africa and South-east Asia and 15 spp. occur in Malesia (Hou, 1996e). In Singapore there are two indigenous species.

Ecology — Coastal beach forest to further inland in primary forest.

Uses — Mainly as timber. See under species.

Key to the Species

1a. Lower surface of pinna glossy, glabrous except at the midrib; rachis and petiole both glabrous. Sepals inermous outside; ovary inermous. Legume unarmed ..... **1. *S. coriacea***

1b. Lower surface of pinna dull, puberulous to pubescent all over; rachis and petiole pubescent to puberulous. Sepals with spiny outgrowths on the upper half outside; ovary shortly spinescent. Legume densely armed with spines to 4 mm long ..... **2. *S. wallichii***

1. *S. coriacea* (Baker) Prain

J. Asiat.. Soc. Beng. 66 ii (1897) 206, 482; Baker in J. D. Hook., Fl. Brit. India 2 (1878) 275; Ridl., Fl. Malay Penins. 1 (1922) 639; Whitmore, Tree fl. Malaya 1 (1972) 271; de Wit, Bull. Jard. bot. Buitenz.. 3:18 (1949) 30; K. Larsen, S.S. Larsen & J.E. Vidal in Fl. Thailand 4 (1984) 98; I.M. Turner, Gdns' Bull., Singapore 47 (1995) 310; Ding Hou, Fl. Males. 1:12 (1996) 697.

Trees 18–33 m tall; trunk cylindric, dbh 31–95 cm, buttresses to 60 cm high. *Leaves*: rachis 5.5–12(–14) cm long; pinna laminas elliptic or ovate, rarely obovate, (3.5–)5–10(–15) by (2.5–)3–5(–7.5) cm, glossy above, apex acute to acuminate, rarely shortly-acuminate, base acute to obtuse; petiolules c. 5 mm long; petiole 2.5–4 cm long. *Panicle* 20–30 cm long, lateral branches to 7 cm long, ± zig-zagging. *Flowers*: bracts and bracteoles ovate-lanceolate, 1.5–3 mm long; sepals yellow, elliptic or lanceolate, 6.5–7.5 by 2.5–3 mm; petal yellow to red, obovate to oblong, 5–7.5 by 2–4 mm, pubescent outside, margins villous; stamens basally connate to c. 3 mm high, free filaments and staminode to 12 mm long, 2 largest anthers ellipsoid, 2.5–3.5 by 1.5 mm long, the rest to 1.5 mm long; ovary ± ellipsoid, 3–4 by 2 mm, woolly along the suture, 4–5-ovuled; style to 11 mm long, glabrous; pedicel 1–2.5 mm long. *Legume* ellipsoid or rarely broadly ellipsoid, 7–10 by 4–6 cm, beak to c. 1 cm long. *Seeds* 2-3 per legume, black, compressed, suborbicular, c. 2 by 2 cm, aril c. 2 by 2 cm.

Distribution — Singapore: rare; Bukit Kallang, Bukit Timah, Nee Soon Swamp Forest. Peninsular Thailand; Malesia: Sumatra (East coast), Peninsular Malaysia (widespread), Borneo (Sabah, Kalimantan) (Hou, 1996e).

Ecology — Primary rain forest or in fresh water swamp forest.

Uses — This species considered the best timber in the genus along with *Sindora velutina* (Whitmore, 1973). The wood oil collected from the tree is used for medicinal purposes (Burkill, 1935).

Notes — This species is a new record for the flora of Singapore. It was first discovered in 1994 by Ali bin Ibrahim in Nee Soon Swamp Forest.

2. *S. wallichii* Benth.

In Hook., Icon. Pl. 11 (1867) sub t. 1018 excl. t. 1017; Baker in J.D. Hook., Fl. Brit. India 2 (1879) 268; Prain., J. Asiat. Soc. Bengal 66, ii (1897) 203, 204, 481, 482; Ridl., J. Straits Brch R. Asiat. Soc. 33 (1900) 75; Ridl., Fl.

Malay Penins. 1 (1922) 637, 638; Symington, Kew Bull. (1938) 75, 77; de Wit, Bull. Jard. bot. Buitenz.. 3:18 (1949) 76; Whitmore, Tree fl. Malaya 1 (1972) 273; Corner, Ways. Trees, 3rd ed. (1988) 445; H. Keng, Concise Fl. Singapore (1990) 39; I.M. Turner, K.S. Chua & H.T.W. Tan, J. Singapore natn. Acad. Sci. 18 & 19 (1990) 73; I.M. Turner, Gdns' Bull., Singapore 45 (1993) 124; Turner, Gdns' Bull., Singapore 47 (1995) 310; Ding Hou, Fl. Males. 1:12 (1996) 708.

Sindora intermedia (Baker) Prain

Trees to 30 m tall; trunk cylindric, dbh (0.7–)1–2 m. *Leaves*: rachis (2–)4–6.5 cm long, pinna laminas elliptic to ovate or obovate, 3.3–9 by 2–5.2 cm, upper surface sometimes puberulous, glossy, apex rounded to broadly acuminate, base rounded; petiolules c. 4 mm long; petiole 1.5–2.5 cm long; stipules falcate, 10–17 by 4–8 mm. *Panicle* 6–25 cm long, lateral branches to 5 cm long, zig-zagging. *Flowers*: bracts and bracteoles lanceolate, to 4 mm long; sepals yellow–green, lanceolate, c. 10 by 3–4 mm; petal elliptic, c. 8 by 3 mm, outside hirsute; stamens unequal, 2 largest: filaments c. 1.5 cm long, anthers 3.5 by 2 mm, 7 others: 0.5–0.7 cm long, anthers c. 3 by 2 mm, staminode 1; ovary rhomboid, c. 5 by 4 mm; style c. 1.5 cm long; stigma capitate; pedicel to 5 mm long. *Legume* green turning black, orbicular to irregularly elliptic, 4–9.5 cm across, beak to 9 mm long. *Seeds* 1–3 per legume, surface with concentric lines, compressed, suborbicular, 1–1.5 by 0.7 cm, aril yellow turning dark brown, c. 2 by 2 cm.

Distribution — Singapore: rare; Botanic Gardens' Jungle, Bukit Timah Nature Reserve (Jungle Falls), Changi Point, Fort Canning Hill, Pulau Sakijang Pelepah, Upper Pierce Reservoir; previously found in Bukit Timah Road. Sumatra (East Coast, Jambi, Palembang, Riau Archipelago), Peninsular Malaysia, Borneo (Sabah, Kalimantan) (Hou, 1996e).

Ecology — Coastal beach forest to further inland in primary forest, sometimes near streams, in groups or solitary. Seedlings can be found near the parent tree. The exudate from the spines of the legume has a strong citrus scent. The seeds are said to be dispersed by rodents which eat the fleshy aril (Ridley, 1930). The aril is fleshy in unripe legumes that have fallen to the ground but in ripe legumes the aril is dark brown and very hard.

Uses — The commercial timber is known as *sepetir* as classified by the Malaysian Timber Board; the pods are medicinal and the wood oil used as an illuminant (Burkill, 1935).

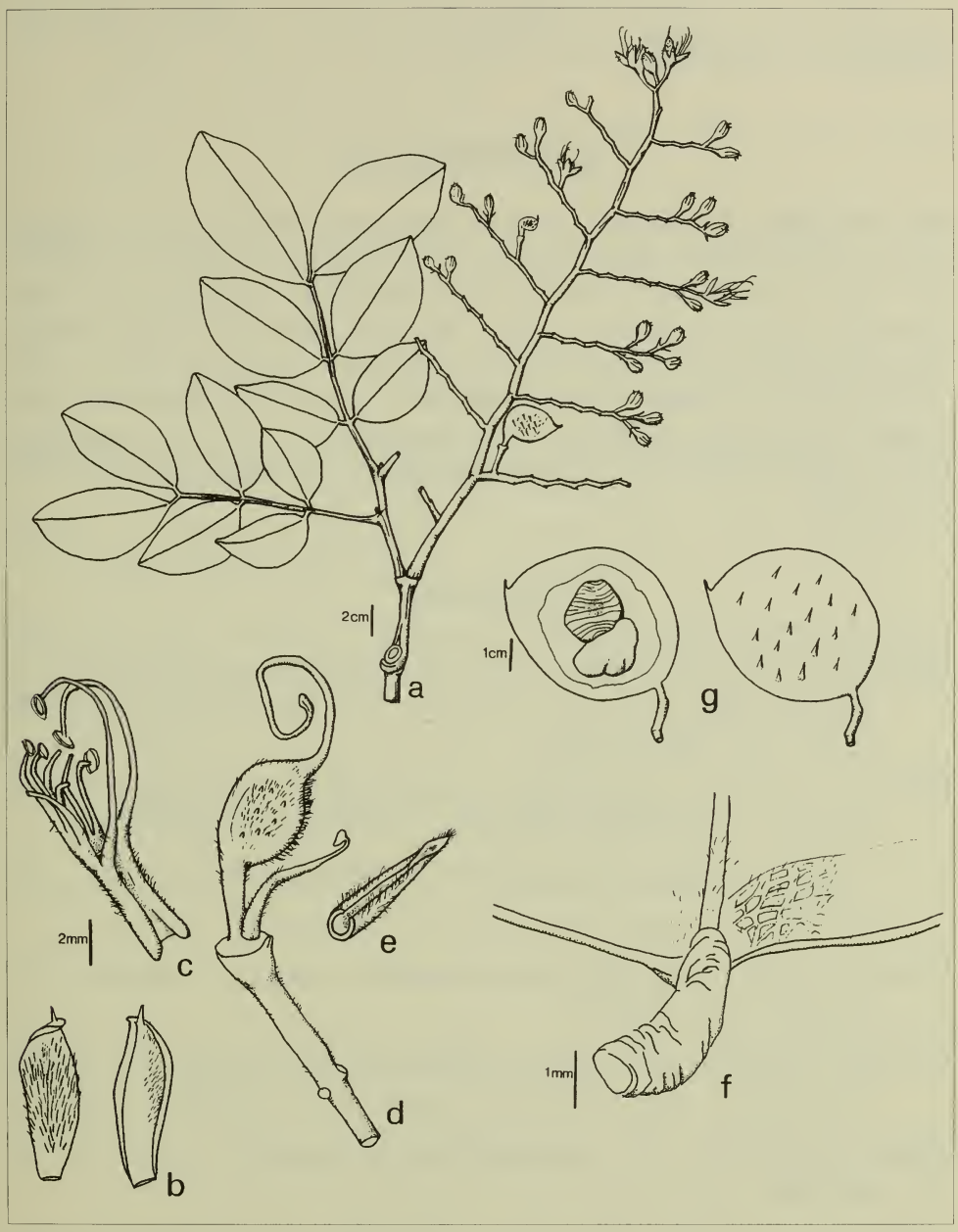

Figure 11. ***Sindora wallichii*** **Benth.** a. Flowering branch with some newly formed legumes; b. Left, inner surface of sepal, right - outer surface of sepal; c. 9 stamens basally connate into a hirsute sheath; d. Ovary on stipe with one free uppermost staminode; e. Isolated petal (adaxial); f. Abaxial view of pinna showing thickened marginal nerve and tertiary venation; g. Legume; left, one valve removed to show arillate seed; right; outer surface of valve. (J.F. Maxwell 78-51)

Notes — Corner (1988) believed that the famous tall tree that stood at Changi and served as a navigational landmark to pilots until 1942, belonged to this species.

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List of Caesalpiniaceae collected in the Republic of Singapore
(includes collector's/s' name, number, date of collection, location, state of specimen.)

Bauhinia semibifida Roxb. var. ***semibifida***

A.H.B. Loo, I.M. Turner, Eel Seah, ALoo 001, 6 July 1996;A.H.B. Loo, Eel Seah, ALoo 007,12 Jul 1996, Nee Soon Swamp Forest, flowering; A.H.B. Loo, C. Boo, J. Yong, L. Chen, I.M. Turner, Eel Seah, ALoo 017(flower buds), 018 (fruiting), 019 (stem), Nee Soon Firing Range; T. M. Leong, ALoo 039, 15 Aug 1996, Rifle Range Road, seedling; B.Y.H. Lee, ALoo 071, Sep 1996, Macritchie Reservoir, flowering; A.H.B. Loo, B.Y.H. Lee, ALoo 078, 11 Oct 1996, Upper Pierce Reservoir (Resam Path), flower buds; A.H.B. Loo, Ali Ibrahim, Eel Seah, Joseph Lai, ALoo 084, 29 Oct 1996, Rifle Range Road (Near Bukit Kallang), flowering.

Caesalpinia bonduc (L.) Roxb.

A. H. B. Loo, Ali Ibrahim, Eel Seah, H. T. W. Tan, ALoo 044, 26 Aug 1996, Pulau Sakijang Pelepah, male flowers; A.H.B. Loo, Ali Ibrahim, Eel Seah, H.T.W. Tan, ALoo 057, 3 Sep 1996, Pulau Sakijang Pelepah, male flowers; A.H.B. Loo, B.C. Soong, Ali Ibrahim, Eel Seah, H.T.W. Tan, S1019, 27 Sep 1996, Pulau Semakau (West), fruiting.

Caesalpinia crista L.

A.H.B. Loo, Ali Ibrahim, Eel Seah, H.T.W. Tan, ALoo 049, 29 Aug 1996, Pulau Tekong (Kg. Salabin), fruiting; A.H.B. Loo, Eel Seah, H.T.W. Tan, ALoo 055, 3 Sep 1996, Pulau Sakijang Pelepah vegetative; N. Tanaka, L. Chen, C. Boo, ALoo 005, 009, Sungei Mandai Kechil, Kg. Fatimah; A.H.B. Loo, ALoo 010, 18 July 1996, Sembawang end, fruiting; A.H.B. Loo, Ali Ibrahim, Eel Seah, H.T.W. Tan, ALoo 025 (stem), ALoo 026 (fruiting), ALoo 027 (seedling), 9 Aug 1996, Western Catchment Area; A.H.B. Loo, Ali Ibrahim, Eel Seah, H.T.W. Tan, ALoo 028, 15 Aug 1996, Pulau Tekong (Kg. Unum), vegetative; A.H.B. Loo, Ali Ibrahim, Eel Seah, ALoo 048, 22 Aug 1996, Pulau Tekong Kechil, vegetative; A.H.B. Loo, Ali Ibrahim, B.C. Soong, Eel Seah, H.T.W. Tan, A.H.B. Loo, Ali Ibrahim, B.C. Soong, Eel Seah, H.T.W. Tan, ALoo 080, 22 Oct 1996, Pulau Terkukor, vegetative; ALoo 081, 22 Oct 1996, Pulau Terkukor, seedling.

Caesalpinia sumatrana Roxb.

A.H.B. Loo, J.A.C.P.L. Looi, ALoo 058, 9 Sep 1996, Bukit Timah Nature Reserve (Cave Path), sapling.

Chamaecrista leschenaultiana *(DC.)* Degener

N. Tanaka, C. Boo, L. Chen, ALoo 043, Jul 1996, Pulau Ubin, vegetative.

Chamaecrista mimosoides (L.) Greene

A.H.B. Loo, ALoo 011, 22 July 1996, Old Upper Thomson Road, flowering and fruiting; A.H.B. Loo, Ali Ibrahim, Eel Seah, H.T.W. Tan, ALoo 034, 20 Aug 1996, Pulau Tekong, flowering and fruiting; A.H.B. Loo, ALoo 072, 11 Oct 1996, Yishun Ave 6, whole plant, nodules; A.H.B. Loo, ALoo 073, 11 Oct 1996, whole plant, nodules; A.H.B. Loo, ALoo 074, 07911 Oct 1996, Yishun Ave 6; A.H.B. Loo, ALoo 085, Nov 1996, Old Upper Thomson Road, flowering and fruiting.

Dialium platysepalum Baker

A.H.B. Loo, T.M. Leong, ALoo 060, 19 Sep 1996, Bukit Timah Nature Reserve (Jungle Falls), 'wallichii', vegetative.

Intsia bijuga (Colebr.) Kuntze

A.H.B. Loo, Eel Seah, D. Wee, Karen, ALoo 020, 1 Aug 1996, Sungei Buloh Nature Reserve, vegetative; A.H.B. Loo, Ali Ibrahim, Eel Seah, H.T.W. Tan, ALoo 024, 9 Aug 1996, Western Catchment Area, fruiting; A.H.B. Loo, Ali Ibrahim, Eel Seah, ALoo 037, 22 Aug 1996, Pulau Tekong Kechil, fruiting, ALoo 038, vegetative.

Koompassia malaccensis Benth.

A.H.B. Loo, ALoo 059, Jul 1996, Botanic Gardens' Jungle, fruits picked up from the ground; A.H.B. Loo, T.M. Leong, ALoo 063, Bukit Timah Nature reserve (Jungle Falls), samaras and seedlings.

Peltophorum pterocarpum (DC.) K. Heyne

A.H.B. Loo, ALoo 003, 12 July, Mandai Road, fruiting; A.H.B. Loo, Ali Ibrahim, Eel Seah, H.T.W. Tan, ALoo 015, 3 Aug 1996, Pulau Hantu, fruiting; Ali Ibrahim, Eel Seah, ALoo 016, 3 Aug 1996, West Coast Road, flowering; A.H.B. Loo, Eel Seah, ALoo 021, 6 Aug 1996, Pulau Sakijang Bendera, fruiting; A.H.B. Loo, ALoo 023, 7 Aug 1996, NUS Campus, flowering and fruiting; Ali Ibrahim, Eel Seah, ALoo 036, 22 Aug 1996, Pulau Tekong Kechil, vegetative, wild?; Ali Ibrahim, Eel Seah, H.T.W. Tan, ALoo 051, 29 Aug 1996, Pulau Tekong, flowering; A.H.B. Loo, Ali Ibrahim, B.C Soong, Eel Seah, H.T.W. Tan, S1010, 27 Sep 1996, Pulau Semakau (West), fruiting, wild?; A.H.B. Loo, B.C Soong, Eel Seah, H.T.W. Tan, S1023, 27 Sep 1996, Pulau Semakau (West), sapling; A.H.B. Loo, Ali Ibrahim, B.C Soong, Eel Seah, H.T.W. Tan, ALoo 067, 1 Oct 1996, Pulau Subar Darat, fruiting; ALoo 082, 22 Oct 1996, Pulau Terkukor, vegetative; A.H.B. Loo, ALoo 086, Nov 1996, NUS Campus, flowering and fruiting.

Senna alata (L.) Roxb.

N. Tanaka, L. Chen, C. Boo, ALoo 002, 13 July 1996, Sungei Mandai Kechil, fruiting; B. Y H. Lee, ALoo 032, 19 Aug 1996, North Bouna Vista Road, flowering, A.H.B. Loo, ALoo 033, 19 Aug 1996, North Bouna Vista Road, flowering; A.H.B. Loo, Ali Ibrahim, B.C Soong, Eel Seah, H.T.W. Tan, ALoo 035, 20 Aug 1996, Pulau Tekong, vegetative; A.H.B. Loo, ALoo 075, 076, 11 Oct 1996, Island Club Road, flowers and fruits; A.H.B. Loo, ALoo 077, 11 Oct 1996, Yishun Ave 6, fruiting.

Senna occidentalis (L.) Link

AH.B. Loo, ALoo 029, 030, 031, 16 Aug 1996, East Coast Road, flowering and fruiting; A.H.B. Loo, Ali Ibrahim, Eel Seah, ALoo 041, 22 Aug 1996, East Coast Road, flowering and fruiting; A.H.B. Loo, ALoo 070, 8 Oct 1996, School of Biologial Sciences Garden (NUS), flowering and fruiting.

Sindora coriacea (Baker) Prain

A.H.B. Loo, Ali Ibrahim, Eel Seah, Joeseph Lai, ALoo 083, 29 Oct 1996, Bukit Kallang (Summit), vegetative.

Sindora wallichii Benth.

A. H. B. Loo, Ali Ibrahim, Eel Seah, ALoo 054, 29 Aug 1996, Netheravon Road, fruiting; ALoo 063, 19 Sep 1996, Bukit Timah Nature Reserve (Jungle Falls), seedlings and fallen fruits.

The following species were not found in the field:

Caesalpinia tortuosa Roxb.
Cynometra ramiflora L. var. ***ramiflora;***
Dialium indum L.var. ***bursa*** (de Wit) Rojo
Dialium indum L. var. ***indum***
Senna hirsuta (L.) Irwin and Barneby var. ***hirsuta;***
Senna obtusifolia (L.) Irwin and Barneby
Senna tora (L.) Roxb.

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The Angiosperm Flora of Singapore Part 7
LIMNOCHARITACEAE

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Limnocharis Humb. and Bonpl.

Pl. aequinoct. 1 (1808) 116; M.R. Hend., Malayan Wild Flowers, Monocotyledons (1954) 202-203; Steenis, Fl. Males. 1:5 (1954) 118-120; Backer & Bakh.*f.*, Fl. Java 3 (1968) 1-2; H. Keng, Orders and Families of Malayan Seed Plants (1969) 287; R.R. Haynes & Holm-Niels., Fl. Neotropica 56 (1992) 8-12.

Emergent, substrate-rooted, fleshy, aerenchyma-rich, laticiferous, aquatic herbs; stem very short. *Leaves* simple, basal, glabrous, long-petiolate, exstipulate. *Inflorescence* an umbel-like cincinnus, bracteate. *Flowers* bisexual, actinomorphic, pedicellate, bracteate; sepals 3, persistent; petals 3; staminodes numerous, tricyclic; stamens numerous, dicyclic; carpels up to 20, fused marginally and basally to form a verticil, placentation laminar; stigma sessile. *Follicetum* enclosed by the persistent sepals; follicles up to 20. *Seeds* many per follicle.

Distribution, Ecology and Uses — See under species.

Notes — *Limnocharis* is often regarded as monotypic, although Duchassaing in Grisebach (Bonplandia 6 (1858) 11) recognised *L. laforestii* as a second species (Haynes and Holm-Nielsen, 1992).

Limnocharis has traditionally been placed in the Butomaceae but more recent treatments follow Cronquist (1981) and his narrow concept of the family. The Limnocharitaceae differ from the Butomaceae *s.s.* by the presence of laticifers, "petiolated leaves that have a terminal pore, a non-petaloid calyx, thin and evanescent petals, and curved seeds and embryos" (Haynes and Holm-Nielsen, 1992).

1. ***Limnocharis flava*** (L.) Buchenau

Abh. naturwiss. Ver. Bremen 2 (1869) 2; Steenis, Fl. Males. 1:5 (1954) 120;

Backer & Bakh.*f*., Fl. Java 3 (1968) 1-2; H. Keng, Gdns' Bull., Singapore 40 (1987) 113; I.M. Turner, K.S. Chua & H.T.W. Tan, J. Singapore Nat. Acad. Sci. 18 & 19 (1990) 63; R.R. Haynes & Holm-Niels., Flora Neotropica 56 (1992) 8-10; I.M. Turner, Gdns' Bull., Singapore 45 (1993) 48.

Alisma flava L.

Herb to 1 m tall. *Leaves*: lamina ovate to suborbicular, to 30 by 23 cm, with 1 midrib and 7–17 secondary veins, apex round or apiculate, with a purple-margined hydathode at the abaxial tip; petiole trigonous, to 85 cm long and c. 8 mm in diam.; sheath to 27 cm long. *Inflorescence* 3–9-flowered, after fruiting becoming stolon-like and forming vegetative shoots; peduncle to 71 cm long and c. 1.5 cm in diam., apically trigonous, basally flattened, sheathless; bracts ovate, fugacious, outermost bracts 2, to c. 3.0 by 2.5 cm, subpedicellate supernumerary buds occasionally develop in their axils in mature inflorescences. *Flowers* cockroach-scented; sepals to 22 by 17 mm; petals with a cream margin and yellow base, suborbicular, to 23 by 25 mm, membranous, fugacious; staminodes yellow, stamens with cream anthers and yellow filaments; carpels cream, laterally compressed; pedicels to c. 5.5 by 1 cm. *Follicetum* subglobose, to 15 mm diam.; follicles yellowish when ripe, semi-circular, laterally compressed with thickened peripheral wall, dehiscent. *Seeds* brown, U-shaped, with thin transverse ridges and broad transverse spines, to c. 1 mm long. (**Figure 1.**)

Distribution — This species from tropical South America, is locally naturalized and was first recorded in Singapore in 1930 (Corlett, 1988). It was recently collected in Choa Chu Kang Muslim Cemetry, Jalan Ulu Seletar, Mandai Road, Marina East and Neo Tiew Road.

Ecology — Aquatic or marsh plants usually found growing in or along water margins, e.g., drains, ditches, freshwater pools or ponds in farm- or wasteland and along roadsides. Usually a perennial, it can be annual through drying of its habitat (Backer & Bakhuizen *f*., 1965). Its presence indicates fertile soils (Ochse, 1931). Flowers open in the morning and fade by afternoon (van Steenis, 1954).

The peduncle of an old inflorescence grows downwards where, on contact with water or mud, it develops leaves and roots so serving as an effective means of vegetative propagation (Backer & Bakhuizen *f*., 1965).

Uses — In West Java, young leaves and inflorescences are eaten and sold in markets (Burkill, 1935), and are eaten raw or cooked with rice by the Javanese (Tanaka, 1976), and also eaten by the Malays (Burkill,

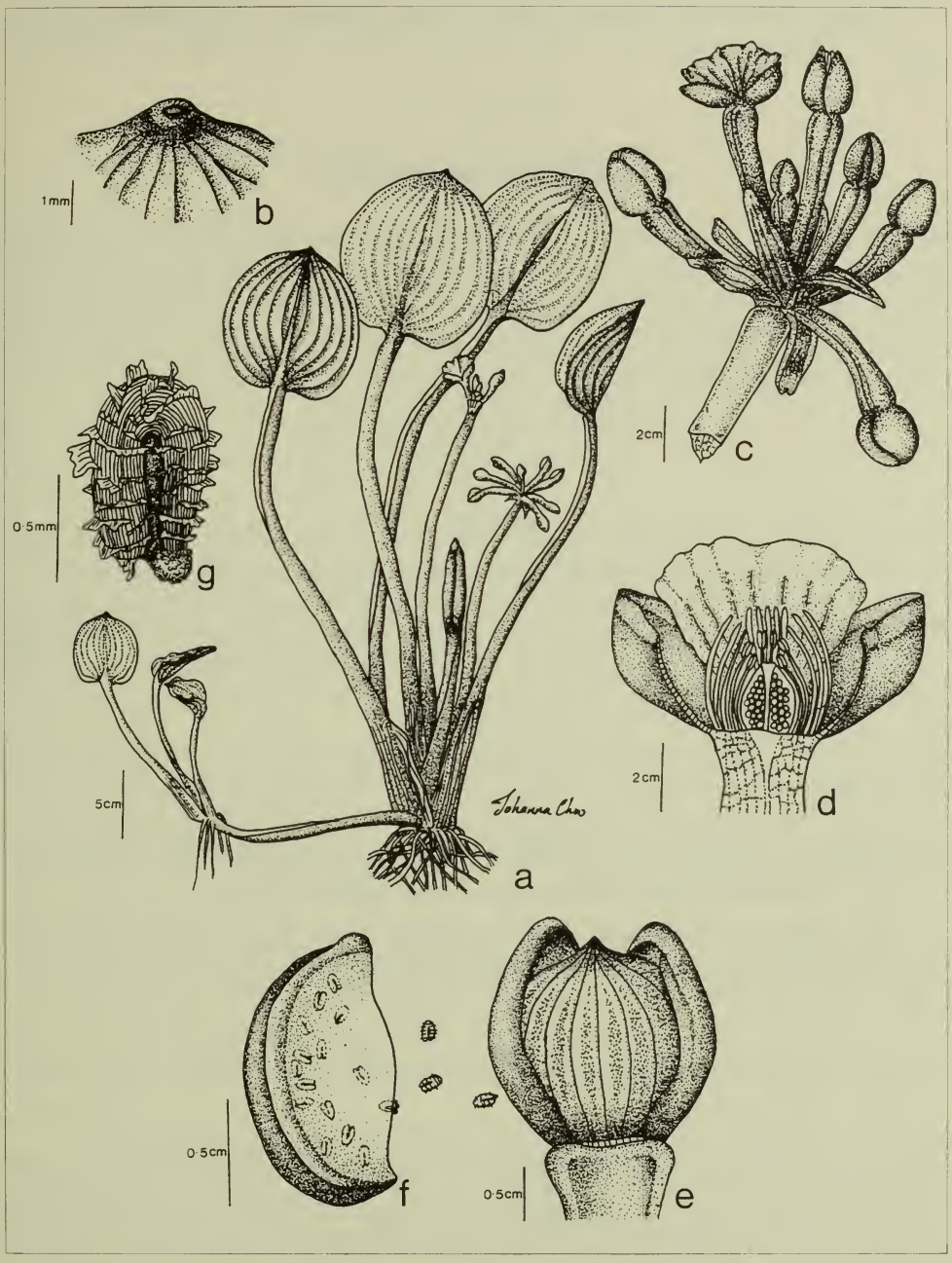

Figure 1. ***Limnocharis flava*** (L.) Buchenau. a. Habit with two newly developed inflorescences and one old inflorescence which has become stoloniferous with a rooting vegetative shoot at its tip. b. Tip of the lamina showing the hydathode. c. A flower and buds of the inflorescence and the peduncle tip. d. Half-flower. e. Follicetum enclosed by two of the three persistent sepals, with one removed, at the tip of the pedicel. f. One follicle and seeds. g. Seed. Del. J.P.S. Choo. P

1935). The raw lamina has a slightly bitter aftertaste. This plant was also used as cattle fodder and green manure in Peninsular Malaysia (Burkill, 1935).

Acknowledgements

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Gazetteer of Limestone Localities in Sabah, Borneo

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Abstract

A map of the 59 limestone localities in the Malaysian state of Sabah, Borneo, is presented together with a table with their co-ordinates, accepted name and the forest area in which they occur.

Introduction

In investigating the limestone flora in Sabah, it became obvious that there was no complete and convenient gazetteer to limestone localities. Limestone hills had been surveyed for their caves with archaeological remains (T. and B. Harrisson, 1971), for caves from which edible bird's nests are collected (Francis, 1987) or for their mollusc fauna (Vermeulen, 1996). None of these sources covers even half the limestone localities. The section on hill and mountain peaks in the Sabah Gazetteer (Tangah and Wong, 1995) lists two limestone hills and gives their altitudes (Dulong Lambu attains 229 m a.s.l. and Madai reaches 359 m) but without mention that they are limestone.

In addition, there are discrepancies in names or the spelling of names. Standardising names has therefore been an important part of this work. For example, the name 'Lobok Buaya' cited by the Harrissons is not to be found on any maps and it was necessary to retrace their route to the site and confirm the accepted name with local villagers. The hill should be called Baladut. Similarly, Batu Punan has been given as an alternative name to Pun Batu, but the local villagers are adamant that it should be called Pun Batu.

Tourist localities are also not accurate in their use of names. Thus the hill in which the Gomantong Cave is located is Bukit Dulong Lambu

(not Bukit Gomantong) and the hill commonly called Batu Putih should correctly be known as Batu Tulug (Batu Putih being the name of the nearby village, not the hill itself).

Two limestone localities are not included in the gazetteer. One is a mollusc site, 'Kirk's Cave, 8 km N of Lahad Datu', for which no co-ordinates are available (Vermeulen, 1996). It is not to be found on any map probably because it is a 'small hill hidden among oil palm estates' and so would not have shown up on aerial photographs if it did not emerge above the tree canopy. Similarly, George Argent (pers. comm.) reports that there are a few large limestone boulders in the river at Danum Valley (Sungai Palum Tambun 4° 58'N 117°49'E), but the source of these has not been found.

Francis (1987) drew attention to the confusion about the number and names of limestone hills in the Sapulut and Sinobang areas, which until recently were very remote and inaccessible. Now the area is riddled with a maze of logging roads and it was possible to visit the Sinobang area on the Sungai Pinangah and obtain information from the local Muruts. This revealed that the hills do not have proper names and that Batu Urun (not a hill but a unique bowl-shaped sunken gorge) is a descriptive name, which merely indicates that it is upriver ('oron' in the Murut language, equivalent to 'ulu' in Malay) and Kelabangan meaning 'a trail' ('labangan' in Murut), is a long cliff face that intermittently outcrops along a stretch about 3-km long (R. Kiew, unpublished data).

The gazetteer was compiled from the following three maps as no single map included all the limestone hills. The mineral map is the most complete.

1. **The Soils of Sabah**. 1974. Scale 1: 125,000. Published for the Sabah Government by the British Overseas Development Administration (Land Resources Division), U.K.

2. **Mineral Distribution Map of Sabah**. 1st edition, 1976. Scale 1: 500,000. Compiled by K.M. Leong, published by The Geological Survey of Malaysia.

3. **Geological Map of Sabah**. 3rd edition, 1985. Scale 1: 500,000. Compiled by P.S. Lim, published by Directorate of Mapping Malaysia. No. 36/87.

Some hills have no names on the maps and these are recorded as unnamed in Table 1 and, where there is a village or river close by, this is given in parenthesis. The position of all hills is shown in Figure 1, the numbers corresponding to the numbered localities in Table 1. The Forest Reserve in which the hill is found is also given, as this is important in considering the conservation status of the limestone flora. The limestone flora is extremely susceptible to burning, which destroys not only the

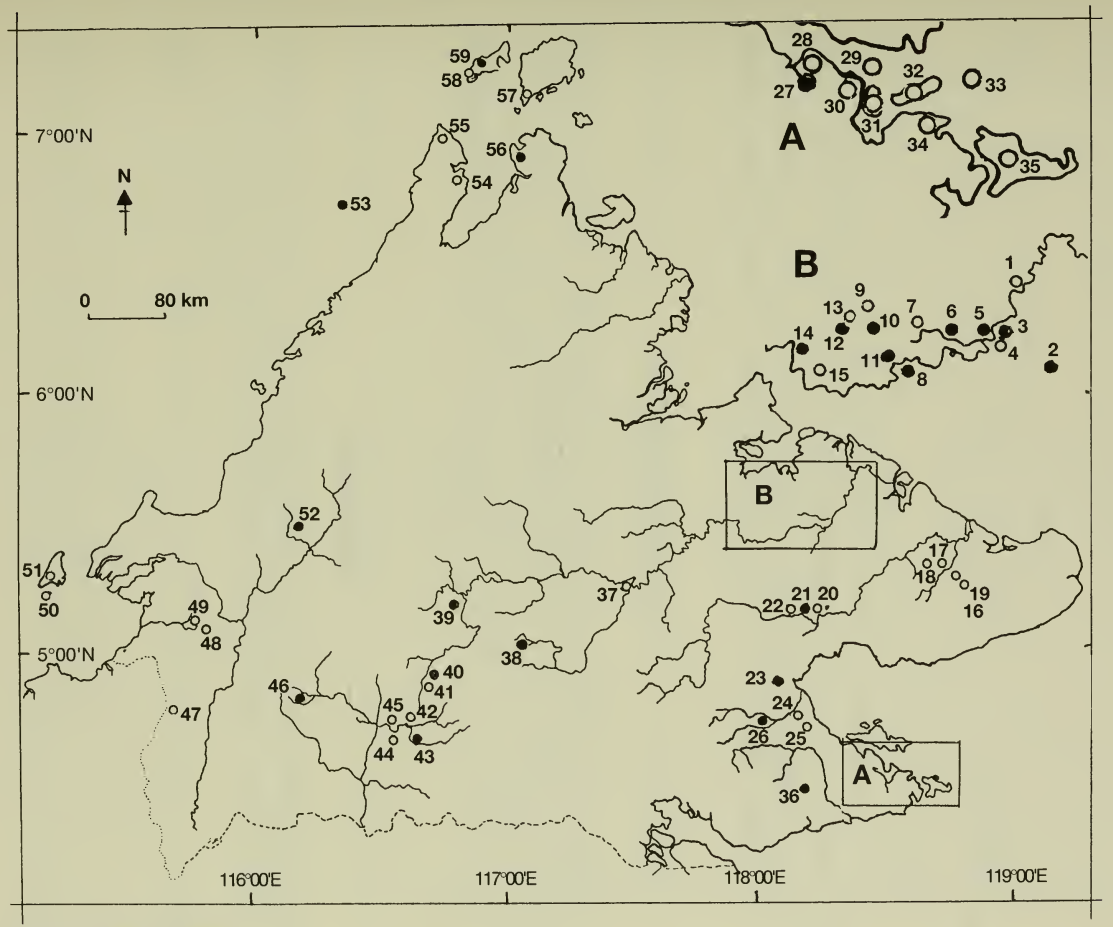

Figure 1. Limestone localities in Sabah.
(Number of the localities corresponds to those in Table 1; solid circles indicate hills from which birds' nests are collected in commercial quantities).

vegetation but also the soil layer, which when no longer protected by vegetation is washed away by subsequent rains leaving the rock bare (Kiew, 1991). The original vegetation on hills that suffered burning in the 1982-83 drought has still not recovered. Protection against fire by a buffer zone of forest is therefore essential for the conservation of the limestone flora. Hills that are not located within Wildlife Reserves or Virgin Jungle Reserves are extremely vulnerable to fire.

Fifty nine limestone localities are listed here. They include the raised coral limestone found on islands, for example in the extreme north and the south east of Sabah, and the inland tower karst hills. It is in these latter that the caves are found.

While we can be confident that all the major hills are listed, there remains the possibility that smaller outcrops (such as 'Kirk's cave' mentioned above), which do not emerge above the forest canopy and so cannot be identified from aerial photographs remain to be mapped. However, based on our field survey their number is likely to be very small.

Acknowledgements

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Table 1. Gazetteer of limestone localities in Sabah

Name of Locality	Coordinate	Forest Reserve
1. Tanjung Batu	5°36'30"N 118°20'00"E	–
2. Ulu Sungai Resang	5°28'45"N 118°23'00"E	–
3. Panggi (Bt. Temanggong Besar)	5°32'15"N 118°18'30"E	Panggi FR
4. Batu Temanggong Kecil	5°32'00"N 118°18'00"E	–
5. Keruak (Cave)	5°31'30"N 118°17'00"E	Keruak VJR
6. Bod Tai Cave	5°31'45"N 118°13'00"E	Bod Tai VJR
7. Unnamed	5°32'45"N 118°9'30"E	–
8. Baladut	5°26'30"N 118°8'00"E	–
9. Kuntos	5°33'00"N 118°4'30"E	Gomantong Protected FR
10. Bukit Dulong Lambu (Gomantong Cave)	5°31'30"N 118°4'15"E	Gomantong VJR
11. Batu Batangan	5°28'00"N 118°6'00"E	–
12. Batu Materis	5°30'30"N 118°2'15"E	–
13. Batu Bunod	5°31'45"N 118°2'45"E	–
14. Batu Supu	5°29'00"N 117°55'15"E	Pin–Supu VJR

15. Batu Tulug	5°25'45"N 117°56'30"E	Pin–Supu VJR
16. Tabin (Batu Quoin)	5°18'00"N 118°44'30"E	Tabin Wildlife Sanctuary
17. Unnamed (Tabin)	5°20'30"N 118°43'30"E	Tabin Wildlife Sanctuary
18. Unnamed (Tabin)	5°21'00"N 118°40'30"E	Tabin Wildlife Sanctuary
19. Unnamed (Tabin)	5°16'15"N 118°46'15"E	Tabin Wildlife Sanctuary
20. Batu Belas	5°7'45"N 118°8'45"E	–
21. Tempadong	5°8'30"N 118°8'15"E	Mensuli VJR
22. Upak	5°7'00"N 118°3'45"E	–
23. Unnamed	4°50'30"N 118°4'45"E	–
24. Gunung Madai	4°43'00"N 118°9'15"E	Madai–Baturong VJR
25. Batu Supad	4°42'15"N 118°10'15"E	Madai–Baturong VJR
26. Bukit Baturong	4°42'00"N 118°00'30"E	Madai–Baturong VJR
27. Batu Tengar Cave (Segarong)	4°34'15"N 118°24'30"E	Segarong Protected FR
& Pababola Cave (Sipit)	4°33'30"N 118°24'15"E	Segarong Protected FR
28. Semorang Cave (Sipit)	4°35'45"N 118°25'00"E	Segarong Protected FR
29. Selangan Island (Sakong)	4°34'45"N 118°30'00"E	Selangan Protected FR

30.	Unnamed (Kampung Ballong)	4°34'00"N 118°28'30"E	–
31.	Pulau Pababag (Sakong)	4°32'30"N 118°29'30"E	Pababag Protected FR
32.	Bait Island (Sakong)	4°32'30"N 118°31'30"E	–
33.	Larapan Island	4°33'45" 118°36'15"E	–
34.	Tanjung Kapur	4°31'30"N 118°32'15"E	–
35.	Bum Bum Island	4°28'00"N 118°40'00"E	–
36.	Batu Pang	4°27'00"N 118°11'00"E	–
37.	Sarupi	5°14'00"N 117°28'30"E	–
38.	Batu Timbang	4°59'00"N 117°6'00"E	Batu Timbang VJR
39.	Melikop	5°5'00"N 116°48'00"E	–
40.	Kelabangan	4°49'30"N 116°38'00"E	Sg. Pinangah Commercial FR
41.	Batu Urun	4°49'30"N 116°38'00"E	Sg. Pinangah Commercial FR
42.	Bandakan	4°43'45"N 116°36'00"E	Sapulut Commercial FR
43.	Batu Punggul	4°38'45"N 116°37'00"E	Sapulut Commercial FR
44.	Unnamed (Labang)	4°39'00"N 116°33'45"E	Sapulut Commercial FR
45.	Sambulyan	4°43'30"N 116°33'30"E	–

46.	Pun Batu	4°48'00"N 116°12'00"E	–
47.	Pulun	4°46'15"N 115°39'45"E	Sabah Forest Industries
48.	Unnamed (Sg. Pangi)	5°5'45"N 115°48'45"E	Gunung Lumaku Protected FR / Sabah Forest Industries
49.	Lakutan	5°7'00"N 115°43'15"E	Sabah Forest Industries
50.	Burong Island	5°14'30"N 115°11'30"E	–
51.	Labuan	5°18'45"N 115°12'00"E	–
52.	Lian Cave	5°29'30"N 116°10'30"E	–
53.	Mantanani Island Besar	6°43'30"N 116°20'30"E	–
	& Kecil	6°43'00"N 116°18'30"E	–
54.	Unnamed	6°50'00"N 116°49'00"E	–
55.	Unnamed	7°1'00"N 116°45'30"E	–
56.	Melobang	6°53'30"N 117°2'30"E	–
57.	Karakit	7°7'15"N 117°5'00"E	Karakit VJR
58.	Kok Simpul & Tg. Kalutan	7°13'00"N 116°52'45"E	Balambangan Protected FR
59.	Tanjung Timohing (Balambangan)	7°17'30"N 116°54'30"E	–

FR forest reserve; VJR virgin jungle reserve; – not found in forest reserve.

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The Botany of the Islands of Mersing District, Johore, Peninsular Malaysia. 1. The Plants and Vegetation of Pulau Tinggi

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Abstract

A list of the vascular plant species found on Pulau Tinggi in the district of Mersing, Johore, Peninsular Malaysia is presented. This has been prepared from herbarium collections in Malaysia and Singapore and covers more than 500 species. A brief outline of the vegetation of the island and the principal species in each vegetation type are given. Pulau Tinggi is mostly covered with lowland dipterocarp forest. The island has good examples of several coastal vegetation types which include the presence of a number of rare seashore species including *Argusia argentea*, *Manilkara kauki*, *Pouteria linggensis* and *Serianthes grandiflora*.

Introduction

Pulau Tinggi (2° 18' N, 104° 7' E) is an island of roughly 14.5 km^2 lying 13 km off the east coast of Johore. Tinggi rises abruptly to a height of 610 m at its summit, with most of the slopes covered in forest. Turner *et al.* (1993) provided a preliminary account of the botany of Pulau Tinggi. Subsequent further research allows a more detailed report to be given here.

Flora

A list of the vascular plants recorded from Pulau Tinggi is given in Appendix 1. Records are taken from herbarium specimens in the Singapore Botanic

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Gardens (SING), School of Biological Sciences, National University of Singapore (SINU), Forest Research Institute Malaysia (KEP) and Department of Botany, Universiti Kebangsaan Malaysia (UKMB). The collections were made by J.B. Feilding who visited Pulau Tinggi in late 1892, I.H. Burkill who was there from 16 to 20 June 1915, Strugnell and Mohd. Yasin in 1952, J. Sinclair in May 1954, F.S.P. Ng in April 1967, A. Zainudin Ismail in 1990 and 1996, and groups from the National University of Singapore in 1991, 1992 and 1996. The list consists of 510 native or naturalized species and 62 cultivated ones.

Vegetation

The main vegetation on Pulau Tinggi is the tropical rain forest that covers the upper slopes of the island. In and around the villages this has been cleared to give way to cultivated areas. Close to the villages these are permanent, higher up the clearings (ladangs) are often abandoned in a form of shifting agriculture. Currently these ladangs are mostly abandoned, probably reflecting a gradual reduction in the permanent population of Pulau Tinggi in recent years, and a shift to employment in the holiday resorts on the island. The seashores support a range of different vegetation types, largely related to their substrate. The sandy beaches differ in their plant community from the more frequent rocky ones. There are also two areas of mangrove vegetation. On some of the coral reef flats there are seagrass meadows. The distribution of the major terrestrial vegetation types is shown in Fig. 1.

Forest

We probably know least about this vegetation type on Tinggi compared to the others. The area of forest is extensive and penetrated by relatively few trails, and collecting from tall trees is technically difficult. Therefore we can only be explicit with regard to the understorey vegetation. Turner *et al.* (1993) described the summit of Tinggi, which is an open grassy area, probably maintained as such by human visitors. The forest on the lower slopes is tall, reaching to 30 m or more in height and contains typical primary forest species such as members of the Dipterocarpaceae and Myristicaceae (see Appendix 1). The palm *Orania sylvicola* is abundant, and there is a zone of bamboo below the summit. This was tentatively identified as *Dendrocalamus hirtellus* by Turner *et al.* (1993), an identification confirmed from further collections by Dr K.M. Wong. Typical forest understorey herbs, such as gingers, aroids and ferns, are to be found in abundance.

The lower edges of the forest grade into secondary forest and

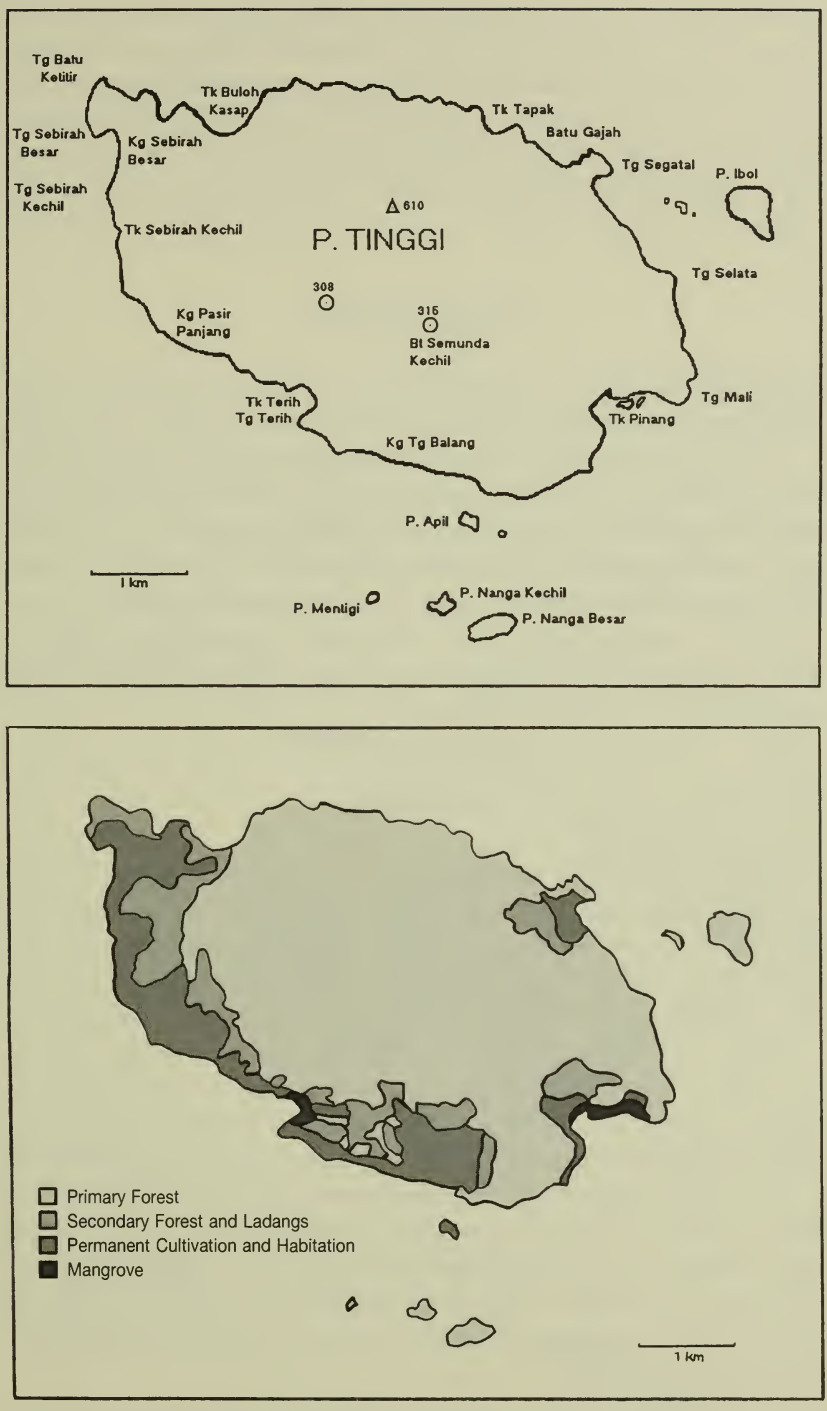

Figure 1. Maps of Pulau Tinggi and its major vegetation types. (P. = Pulau, Tg = Tanjung, Tk = Telok, Kg = Kampung, Bt = Bukit; spot heights in metres)

abandoned ladangs. Common species in this region include *Vitex pinnata* and *Melastoma malabathricum*. Old crop plants may also be found. We came across the garden pandan, *Pandanus amaryllifolius* growing along one stream, and the climber *Tinospora crispa*, which is grown for its medicinal uses, in another area. Newly cleared areas, if not planted, soon give way to pioneering plants such as *Trema tomentosa*, *Chromolaena odorata* and *Macaranga heynei*.

Cultivated Areas

The kampung houses on Tinggi are set among the typical tumult of ornamental and useful plants seen in any Malay village. Coconut palms (*Cocos nucifera*) dominate the flat areas near the sea, though their cultivation appears to be largely neglected at present. The coconut groves are mostly carpetted with cattle-grazed lallang (*Imperata cylindrica*) and clumps of *Lantana camara*. The kwini (*Mangifera odorata*) is the only crop currently exported from Pulau Tinggi. Other commonly grown trees include rubber (*Hevea brasiliensis*), clove (*Syzygium aromaticum*) and nutmeg (*Myristica fragrans*). The attractive herb *Tacca palmata* is quite common in the plantations.

Sea Shores

Most of Tinggi's coastline is rocky, usually of large boulders. The north coast is mostly inaccessible, even by boat. Common trees found just above the high tide line are *Memecylon edule*, *Allophylus cobbe*, *Ficus superba* and *Pouteria obovata*. *Cycas rumphii*, *Glycosmis mauritiana*, *Premna serratifolia* and *Ficus tinctoria* ssp. *gibbosa* are shrubby species also common on the rocks. *Pandanus dubius* is abundant on the north coast in such situations. The rocky promontories most exposed to salt spray from the sea support *Pemphis acidula* or *Xylocarpus rumphii*. Ferns are often encountered creeping over the surface of the rocks. These include *Davallia solida*, *Drynaria quercifolia*, *Phymatosorus scolopendria* and *Pyrrosia lanceolata*. Cracks support other herbs, notably the naturalized alien *Kalanchoe pinnata*, *Dianella ensifolia* and *Asplenium macrophyllum*. *Hoya verticillata* and *Dischidia major* are common epiphytes. The orchids *Dendrobium crumenatum* and *Aerides odorata* can be found growing both epiphytically and on rocks.

On the sandy beaches, mostly found in the bays on the south and east coasts, the creepers *Ipomoea pes-caprae*, *Ipomoea littoralis*, *Vitex trifolia* and *Cyperus stoloniferus* can be found. The back of the beach is typically

lined with shrubs of *Scaevola taccada*, *Pandanus odoratissimus* and *Dendrolobium umbellatum* behind which grow trees such as *Hibiscus tiliaceus*, *Peltophorum pterocarpum*, *Terminalia catappa*, *Barringtonia asiatica* and *Guettarda speciosa*. Less frequently encountered are *Thespesia populnea*, *Cordia subcordata* and *Casuarina equisetifolia*. Individual trees of *Erythrina fusca*, *Erythrina variegata* and *Hernandia nymphaeifolia* are to be found at Telok Seruang.

Mangrove

There are two areas of mangrove vegetation on Pulau Tinggi. At Telok Terih there is a range of mangrove habitats at the mouth of the Sungai Terih Besar. Telok Pinang contains a smaller area of mangrove.

A preliminary survey at Telok Terih found that an almost pure stand of *Rhizophora apiculata* occupies the seaward front of the mangrove where the substrate is muddiest (Fig. 2). Patches of different species, including

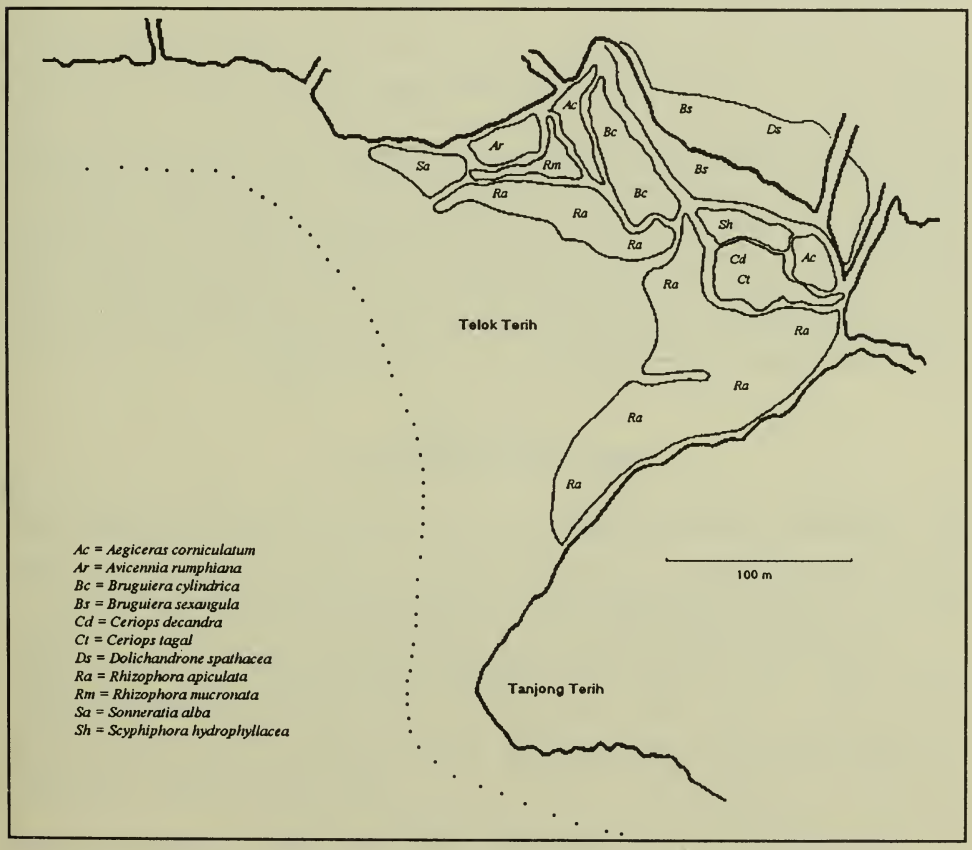

Figure 2. Map of the mangrove vegetation found at Telok Terih, Pulau Tinggi.

Avicennia rumphiana, *Bruguiera cylindrica* and *Aegiceras corniculatum* are found behind. The back mangrove is quite diverse with big trees of *Xylocarpus granatum* and *Bruguiera gymnorrhiza*. *Dolichandrone spathacea*, *Cynometra ramiflora* and *Bruguiera sexangula* also occur here, with an understorey of *Acrostichum aureum* and *Acrostichum speciosum*. The trees on the rocky fringe bordering the mangrove support many epiphytes including the rubiaceous myrmecophyte *Hydnophytum formicarum* and the clubmoss *Huperzia carinata*.

The Telok Pinang mangrove is dominated by *Rhizophora apiculata* and *Rhizophora stylosa* but with an admixture of a number of other species including *Ceriops decandra* and *Bruguiera gymnorrhiza*. There appears to be more human utilization of the mangroves in Telok Pinang than Telok Terih, but there is evidence that the local people may be replanting areas cut, presumably for fuel or for use as poles. Species found at Telok Terih but not seen at Telok Pinang include *Avicennia alba*, *Bruguiera sexangula* and *Ceriops tagal*. The mangroves on Tinggi are notable for the scarcity of *Sonneratia alba* and *Avicennia alba*.

Sea Grasses

We have located herbarium specimens of three species of sea grass collected from the coastal waters of Pulau Tinggi. There are fairly extensive areas of sea grass in front of Kampung Tanjung Balang, mostly of *Cymodocea rotundifolia* interspersed with the smaller *Halodule uninervis*. Burkill also collected *Thallassia hemprichii*. *Enhalus acoroides* shoots were found among the seashore flotsam, but no plants were seen growing around the island. Japar (1994) also reports *Halophila ovalis* from Tinggi.

Botanical Significance

We now have records for more than 500 species of vascular plant from Pulau Tinggi. However, we believe that this is likely to represent less than half of the flora of the island. Many forest species remain uncollected.

As outlined by Turner *et al.* (1993), the most important collections from Pulau Tinggi are those of *Pandanus lais* and *Canarium hirsutum*. The former has not been collected since 1915, but we have located the latter. Several plants were encountered near the path running behind the mangroves in Telok Terih. It grows at the edge of secondary forest and becomes reproductive at a fairly small size (4-5 m tall).

The most exciting of the recent collections is the discovery of a new east coast locality for *Argusia argentea*. Until now it was only known from

Pulau Tengah in Johore. This adds to the number of rare seashore species that have been recorded from Pulau Tinggi. Others in this category include *Serianthes grandiflora*, *Manilkara kauki* and *Pouteria linggensis*.

Didymocarpus tiumanicus was believed to be endemic to Pulau Tioman (Henderson 1930, as *Paraboea tiumanica*), but we have now found it on Tinggi, and it has been collected on Pulau Pemanggil also. Thus this species has to be added to the flora of Johore, and must be thought of as a Tioman Archipelago endemic, rather than being confined to the one island. Another species not previously reported from Johore is *Mallotus philippensis*.

One sterile collection was identified by Mr K.M. Kochummen as possibly *Swintonia acuta*, a species only previously recorded from Borneo. Fertile material is needed to confirm the occurrence of this species in Peninsular Malaysia.

Acknowledgements

The members of 1996-97 NUS Botany Honours Class are thanked for their invaluable assistance in collecting and making observations on Pulau Tinggi. That trip was arranged by the Malaysian Nature Society and Abdullah Piee, Nik Mohamad and Dr Loh Chi Leong are thanked for their company on Tinggi. A number of people assisted with identification of collections, particularly Haji Sidek Kiah and Ali Ibrahim at the Singapore Botanic Gardens and Chua Keng Soon at NUS. Mr K.M. Kochummen and Dr Saw Leng Guan are thanked for their assistance with the Anacardiaceae, and Dr Wong Khoon Meng for confirming the identity of the Tinggi bamboo.

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Japar, S.B. 1994. Status of seagrass resources in Malaysia. In: C.R. Wilkinson, S. Sudara & L.M. Chou. *Proceedings, Third ASEAN-Australia Symposium on Living Coastal Resources*, pp. 283-289 Vol. 1 Australian Institute of Marine Science, Townsville.

Turner, I.M. 1995. A catalogue of the vascular plants of Malaya. *Gardens' Bulletin Singapore* **47**: 1–757.

Turner, I.M., H.T.W. Tan, K.S. Chua, P.T. Chew, & Haji Samsuri bin Haji Ahmad 1993. A botanical reconnaisance of Pulau Tinggi, Johore. *Malayan Nature Journal* **46**: 157–168.

Appendix 1. A list of species collected from Pulau Tinggi.
One representative herbarium collection is cited for each species. Species only found in cultivation, or as relics of cultivation, are indicated as such by 'c' in the margin. Nomenclature follows Turner (1995) where possible.

PTERIDOPHYTA

Adiantaceae

Adiantum stenochlamys Baker - Strugnell KEP 70933 (KEP)
Taenitis blechnoides (Willd.) Sw. - PT96 649 (SINU)

Aspleniaceae

Asplenium macrophyllum Sw. - PT96-186 (SINU)
Asplenium nidus L. - PT96-217 (SINU)
Asplenium tenerum G. Forst. - PT96-131 (SINU)

Blechnaceae

Blechnum finlaysonianum Wall. *ex* Hook. & Grev. - J.W.H.Yong PT5 (SINU)

Davalliaceae

Davallia angustata Wall. *ex* Hook. & Grev. - I.M. Turner PT13 (SINU)
Davallia denticulata (Burm.*f.*) Mett. *ex* Kuhn - PT96-423 (SINU)

Dennstaedtiaceae

Lindsaea doryophora K.U. Kramer I.M.Turner PT4 (SINU)
Lindsaea lucida Blume - I.H. Burkill S.F.N. 947 (SING)
Pteridium esculentum (G. Forst.) Cockayne - I.M. Turner PT66 (SINU)
Tapeinidium pinnatum (Cav.) C.Chr. - I.M. Turner PT31 (SINU)
Tectaria griffithii (Baker) C. Chr. - I.M.Turner PT78 (SINU)
Tectaria semipinnata (Roxb.) C.V. Morton - Radhika Ramadas PT99 (SINU)
Tectaria singaporeana (Hook. & Grev.) Copel. - PT96-113 (SINU)

Dryopteridaceae

Ctenitis vilis (Kunze) Ching - I.M.Turner PT33 (SINU)
Heterogonium giganteum (Blume) Holttum - I.M.Turner PT78 (SINU)
Pleocnema irregularis (C. Presl) Holttum - I.H. Burkill S.F.N. 923 (SING)

Gleicheniaceae

Dicranopteris linearis (Willd.) Spreng. - PT96-230 (SINU)
Stichurus truncatus (Willd.) Nakai - I.M.Turner PT53 (SINU)

Hymenophyllaceae

Cephalomanes javanicum (Blume) Bosch - I.H. Burkill S.F.N. 937 (SING)
Hymenophyllum polyanthos Sw. - I.M.Turner PT14 (SINU)

Lomariopsidaceae

Teratophyllum rotundifoliatum (R. Bonap.) Holttum - I.M.Turner PT76 (SINU)

Lycopodiaceae

Huperzia carinata (Desv. *ex* Poir.) Trevis. - PT96-208 (SINU)
Huperzia phlegmaria (L.) Rothm. - PT96 202 (SINU)

Marattiaceae

Angiopteris evecta (G. Forst.) Hoffm. - PT96-107 (SINU)

Oleandraceae

Nephrolepis auriculata (L.) Trimen - I.M.Turner PT9 (SINU)

Polypodiaceae

Colysis pedunculata (Hook. & Grev.) Ching - I.M.Turner PT55 (SINU)
Drynaria quercifolia (L.) J. Sm. - PT96 238 (SINU)
Drynaria sparsisora (Desv.) T. Moore - PT96-388 (SINU)
Lecanopteris crustacea Copel. - J.W.H.Yong PT104 (SINU)
Phymatosorus scolopendria (Burm.*f.*) Pic.Serm. - PT96-332 (SINU)
Pyrrosia lanceolata (L.) Farwell - PT96 451 (SINU)
Pyrrosia piloselloides (L.) M.G. Price - PT96-457 (SINU)
Selliguea heterocarpa (Blume) Blume - I.M.Turner PT26 (SINU)

Pteridaceae

Acrostichum aureum L. - PT96-644 (SINU)
Acrostichum speciosum Willd. - PT96-312 (SINU)
Pteris ensiformis Burm.*f.* - PT96-654 (SINU)

Schizaeaceae

Lygodium circinnatum (Burm.*f.*) Sw. - PT96-378 (SINU)
Lygodium flexuosum (L.) Sw. - PT96-364 (SINU)
Schizaea digitata (L.) Sw. - PT96-671 (SINU)

Selaginellaceae

Selaginella intermedia (Blume) Spring - PT96-285 (SINU)
Selaginella padangensis Hieron. - I.H. Burkill s.n., June 1915 (SING)
Selaginella willdenowii (Desv.) Baker - PT96-106 (SINU)

Thelypteridaceae

Amphineuron opulentum (Kaulf.) Holttum - PT96-637 (SINU)
Christella parasitica (L.) Lév. - J. Sinclair, S.F.N. 40291 (SING)
Cyclosorus interruptus (Willd.) H. Itô - PT96-491 (SINU)
Pronephrium menisciicarpon (Blume) Holttum - I.M.Turner PT43 (SINU)
Pronephrium repandum (Fée) Holttum - PT96-683 (SINU)

Vittariaceae

Antrophyum callifolium Blume - PT96-124 (SINU)

SPERMATOPHYTA

Acanthaceae

Asystasia nemorum Nees - PT96-53 (SINU)
c *Justicia gendarussa* Burm.*f.* - PT96-15 (SINU)
c *Thunbergia affinis* S. Moore - PT96-4 (SINU)

Actinidiaceae

Saurauia pentapetala (Jack) Hoogland - D.J.Metcalfe PT71 (SINU)

Alangiaceae

Alangium kurzii Craib - A. Zainudin AZ 5785 (UKMB)
Alangium rotundifolium (Hassk.) Bloemb. - I.H. Burkill S.F.N. 907 (SING)

Amaranthaceae

Amaranthus lividus L. - PT96-657 (SINU)
Amaranthus spinosus L. - PT96-679 (SINU)

Amaryllidaceae

Crinum asiaticum L. - PT96-231 (SINU)

Anacardiaceae

Campnosperma auriculatum (Blume) Hook.*f.* - Mohd. Yasin bin Aboo, KEP 70930 (KEP)

c *Mangifera indica* L. - PT96-609 (SINU)
Mangifera magnifica Kochummen - A. Zainudin AZ 5922 (UKMB)
Mangifera pentandra Hook.*f.* - I.H. Burkill *s.n.*, June 1915 (SING)
Melanochyla caesia (Blume) Ding Hou - PT96-160 (SINU)
Parishia maingayi Hook.*f.* - A. Zainudin AZ 5921 (UKMB)
c *Spondias cytherea* Sonn. - PT96-153 (SINU)
Swintonia cf. *acuta* Engl. - A. Zainudin AZ 5841 (UKMB)

Anisophylleaceae
Anisophyllea corneri Ding Hou - PT96-525 (SINU)

Annonaceae
c *Annona squamata* L. - PT96-63 (SINU)
Desmos dasymaschalus (Blume) Safford - A. Zainudin AZ 5896 (UKMB)
Phaeanthus ophthalmicus (Roxb. *ex* G. Don) J. Sinclair - PT96-664 (SINU)
Polyalthia cauliflora Hook.*f.* & Thomson - Samsuri 61 (SINU)
Uvaria cordata (Dunal) Alston - Samsuri 62 (SINU)
Uvaria hirsuta Jack - I.H. Burkill S.F.N. 872 (SING)

Apocynaceae
Alstonia angustiloba Miq. - I.M.Turner PT42 (SINU)
Alstonia scholaris (L.) R.Br. - A. Zainudin AZ 5859 (UKMB)
Cerbera manghas L. - PT96-172 (SINU)
Ichnocarpus serpyllifolius (Blume) P.I. Forst. - J.W.H. Yong PT25 (SINU)
c *Thevetia peruviana* (Pers.) K. Schum. - PT96-303 (SINU)

Araceae
Aglaonema simplex Blume - I.H. Burkill S.F.N. 912 (SING)
Alocasia beccarii Engl. - I.M.Turner PT11 (SINU)
Alocasia denudata Endl. - PT96-101 (SINU)
Alocasia longiloba Miq. - A. Zainudin AZ 5787 (UKMB)
Anadendrum montanum (Blume) Schott - A. Zainudin AZ 3259 (UKMB)
c *Caladium bicolor* (Aiton) Vent. - PT96-167 (SINU)
Homalomena angustifolia (Jack) Hook.*f.* - I.H. Burkill S.F.N. 908 (SING)
Homalomena propinqua Schott - PT96-158 (SINU)
Homalomena sagittifolia Jungh. *ex* Schott - I.H. Burkill S.F.N. 931 (SING)
Rhaphidophora korthalsii Schott - J. Feilding *s.n.*, 1892 (SING)
Schismatoglottis calyptrata (Roxb.) Zoll. & Moritzi - I.H. Burkill S.F.N. 883 (SING)
Schismatoglottis wallichii Hook.*f.* - I.H. Burkill S.F.N. 932 (SING)
Scindapsus pictus Hassk. - J.C.W.Chee PT94 (SINU)

Araliaceae
Arthrophyllum diversifolium Blume - PT96-402 (SINU)
Arthrophyllum maingayi Philipson - A. Zainudin AZ 5961 (UKMB)
Macropanax maingayi (C.B. Clarke) Philipson - A. Zainudin AZ 3251 (UKMB)
Schefflera elliptica (Blume) Harms - I.H. Burkill S.F.N. 886 (SING)

Aralidiaceae
Aralidium pinnatifidum (Jungh. & de Vriese) Miq. - PT96-620 (SINU)

Asclepiadaceae
Dischidia major (Vahl) Merr. - PT96-237 (SINU)
Hoya diversifolia Blume - J. Feilding *s.n.*, 27 Nov. 1892 (SING)

Hoya elliptica Hook.*f.* - A. Zainudin AZ 5878 (UKMB)
Hoya multiflora Blume - I.M.Turner 91-31 (SINU)
Hoya verticillata (Vahl) G. Don - I.H. Burkill S.F.N. 898 (SING)

Avicenniaceae
Avicennia alba Blume - PT96-613 (SINU)
Avicennia rumphiana Hallier *f.* - PT96-175 (SINU)

Balsaminaceae
c *Impatiens balsamina* L. - PT96-55 (SINU)

Begoniaceae
Begonia herveyana King - J. Feilding *s.n.*, Oct. 1892 (SING)

Bignoniaceae
Dolichandrone spathacea (L.*f.*) K. Schum. - PT96-651 (SINU)

Bombacaceae
c *Ceiba pentandra* (L.) Gaertn. - PT96-16 (SINU)
c *Durio zibethinus* L. - PT96-33 (SINU)

Boraginaceae
Argusia argentea (L.*f.*) Heine - PT96-257 (SINU)
Cordia dichotoma G. Forst. - A. Zainudin AZ 3201 (UKMB)
Cordia subcordata Lam. - PT96-276 (SINU)

Burmanniaceae
Burmannia championii Thwaites - PT96-511 (SINU)

Burseraceae
Canarium hirsutum Willd. - I.H. Burkill S.F.N. 906 (SING)
Canarium littorale Blume - A. Zainudin AZ 5864 (SING)
Canarium pilosum Benn. - I.H. Burkill S.F.N. 862 (SING)
Santiria apiculata Benn. - A. Zainudin AZ 5919 (UKMB)
Santiria rubiginosa Blume - A. Zainudin AZ 5836 (UKMB)

Capparaceae
Cleome rutidosperma DC. - PT96-14 (SINU)

Casuarinaceae
Casuarina equisetifolia J.R. Forst. & G. Forst. - PT96-176 (SINU)

Celastraceae
Bhesa paniculata Arn. - J.W.H.Yong PT10 (SINU)
Loesneriella pauciflora (DC.) A.C. Sm. - PT96-277 (SINU)
Salacia korthalsiana Miq. - I.M.Turner PT115 (SINU)
Salacia macrophylla Blume - I.M.Turner PT83 (SINU)

Chloranthaceae
Chloranthus erectus (Buch.-Ham.) Verdc. - PT96-515 (SINU)

Chrysobalanaceae
Maranthes corymbosa Blume - A. Zainudin AZ 5931 (UKMB)

Colchicaceae
c *Gloriosa superba* L. - PT96-49 (SINU)

Combretaceae
Lumnitzera littorea (Jack) Voigt - PT96-298 (SINU)
Lumnitzera racemosa Willd. - PT96-272 (SINU)
Terminalia catappa L. - PT96-680 (SINU)

Commelinaceae

Amischotolype gracilis (Ridl.) I.M. Turner - PT96-281 (SINU)

Murdannia nudiflora (L.) Brenan - J. Feilding *s.n.*, 1892 (SING)

Compositae

Acmella paniculata (Wall. *ex* DC.) R.K. Jansen - Y.F. Chan & M.C. Loh PT48 (SINU)

Ageratum conyzoides L. - PT96-74 (SINU)

Blumea balsamifera (L.) DC. - J. Sinclair, S.F.N. 40282 (SING)

Chromolaena odorata (L.) R.M. King & H. Rob. - PT96-653 (SINU)

Conyza bonariensis (L.) Cronquist - I.H. Burkill *s.n.*, June 1915 (SING)

c *Cosmos sulphureus* Cav. - PT96-52 (SINU)

Erechtites valerianifolia (Wolf) DC. - PT96-221 (SINU)

Synedrella nodiflora (L.) Gaertn. - A. Zainudin AZ 5939 (UKMB)

Vernonia cinerea (L.) Less. - PT96-650 (SINU)

Vernonia patula (Dryand.) Merr. - PT96-259 (SINU)

Wollastonia biflora (L.) DC. - PT96-386 (SINU)

c *Zinnia elegans* Jacq. - PT96-142 (SINU)

Connaraceae

Cnestis palala (Lour.) Merr. - A. Zainudin AZ 5881 (UKMB)

Convallariaceae

Peliosanthes teta Andr. ssp. *humilis* (Andr.) Jessop - D.J.Metcalfe PT60 (SINU)

Convolvulaceae

c *Ipomoea batatus* (L.) Lam. - PT96-94 (SINU)

Ipomoea littoralis Blume - I.H. Burkill S.F.N. 889 (SING)

Ipomoea pes-caprea (L.) R.Br. - PT96-199 (SINU)

Merremia peltata (L.) Merr. - J. Sinclair, S.F.N. 40281 (SING)

Costaceae

Costus globosus Blume - PT96-159 (SINU)

Crassulaceae

c *Kalanchoe laciniata* (L.) DC. - I.H. Burkill S.F.N. 926 (SING)

Kalanchoe pinnata (Lam.) Pers. - PT96-339 (SINU)

Cycadaceae

Cycas rumphii Miq. - PT96-320 (SINU)

Cymodoceaceae

Cymodocea rotundata Ehrenb. & Hempr. - PT96-235 (SINU)

Halodule uninervis (Forssk.) Asch. - I.H. Burkill S.F.N. 899 (SING)

Cyperaceae

Cyperus dubius Rottb. - PT96-247 (SINU)

Cyperus javanicus Houtt. - PT96-442 (SINU)

Cyperus rotundatus L. - A. Zainudin AZ 5769 (UKMB)

Cyperus stoloniferus Retz. - PT96-248 (SINU)

Fimbristylis cymosa R.Br. - A. Zainudin AZ 5768 (UKMB)

Fimbristylis dichotoma (L.) Vahl - PT96-318 (SINU)

Hypolytrum nemorum (Vahl) Spreng. - PT96-411 (SINU)

Kyllinga brevifolia Rottb. - I.H. Burkill *s.n.*, June 1915 (SING)

Kyllinga polycephala Willd. *ex* Kunth - PT96-100 (SINU)

Mapania cuspidata (Miq.) Uittien var. *petiolata* (C.B. Clarke) Uittien - PT96-416 (SINU)

Scleria biflora Roxb. - PT96-462 (SINU)
Scleria levis Retz. - PT96-459 (SINU)
Scleria lithosperma (L.) Sw. - PT96-224 (SINU)
Scleria purpurascens Steud. - PT96-279 (SINU)

Dilleniaceae
Tetracera indica (Christ. & Panz.) Merr. - PT96-346 (SINU)
Tetracera scandens (L.) Merr. - PT96-325 (SINU)

Dipterocarpaceae
Dipterocarpus grandiflorus (Blanco) Blanco - I.H. Burkill S.F.N. 930 (SING)
Shorea macroptera Dyer - Mohd. Yasin bin Aboo, KEP 70928 (KEP)
Shorea materialis Ridl. - I.H. Burkill S.F.N. 946 (SING)
Shorea pauciflora King - Mohd. Yasin bin Aboo, KEP 70941 (KEP)

Dioscoreaceae
Dioscorea bulbifera L. - A. Zainudin AZ 5894 (UKMB)

Dracaenaceae
Dracaena maingayi Hook.*f.* - PT96-342 (SINU)
Dracaena umbratica Ridl. - A. Zainudin AZ 3219 (UKMB)

Ebenaceae
Diospyros cauliflora Blume - A. Zainudin AZ 5916 (UKMB)
Diospyros ferrea (Willd.) Bakh. - PT96-189 (SINU)
Diospyros lanceifolia Roxb. - I.H. Burkill S.F.N. 874 (SING)
Diospyros malabarica (Descr.) Kostel. - PT96-447 (SINU)
Diospyros toposia Buch.-Ham. - I.H. Burkill S.F.N. 943 (SING)

Elaeocarpaceae
Elaeocarpus petiolatus (Jack) Wall. - A. Zainudin AZ 5858 (UKMB)

Erythroxylaceae
Erythroxylum cuneatum (Miq.) Kurz - PT96-315 (SINU)

Euphorbiaceae
c *Acalypha hispida* Burm.*f.*- PT96-12 (SINU)
Antidesma coriaceum Tul. - A. Zainudin AZ 3222 (UKMB)
Antidesma cuspidatum Müll.Arg. - PT96-476 (SINU)
Antidesma montanum Blume - F.S.P. Ng, FRI 5031 (KEP)
Antidesma velutinosum Blume - A. Zainudin AZ 5831 (UKMB)
c *Baccaurea motleyana* (Müll.Arg.) Müll.Arg. - PT96-458 (SINU)
Baccaurea racemosa (Reinw.) Müll.Arg. - PT96-145 (SINU)
Baccaurea ramiflora Lour. - PT96-162 (SINU)
Breynia reclinata (Roxb.) Hook.*f.* - PT96-412 (SINU)
Breynia vitis-idaea (Burm.*f.*) C.E.C. Fisch. - D.J.Metcalfe PT49 (SINU)
Bridelia tomentosa Blume - A. Zainudin AZ 5814 (UKMB)
Claoxylon longifolium (Blume) Endl. *ex* Hassk. - A. Zainudin AZ 3260 (UKMB)
Croton argyratus Blume - A. Zainudin AZ 5862 (UKMB)
Endospermum diadenum (Miq.) Airy Shaw - D.J.Metcalfe PT2 (SINU)
Euphorbia cyathophora Murr. - PT96-234 (SINU)
Euphorbia hirta L. - PT96-50 (SINU)
c *Euphorbia pulcherrima* Willd. - A. Zainudin AZ 3237 (UKMB)
Excoecaria agallocha L. - PT96-218 (SINU)

Glochidion fuscum (Müll.Arg.) Boerl. - A. Zainudin AZ 3210 (UKMB)
Glochidion penangense (Müll.Arg.) Airy Shaw - PT96-393 (SINU)
c *Hevea brasiliensis* (Willd. *ex* A. Juss.) Müll.Arg. - PT96-485 (SINU)
c *Jatropha gossypiifolia* L. - PT96-677 (SINU)
Macaranga heynei I.M. Johnst. - PT96-166 (SINU)
Macaranga gigantea (Rchb.*f.* & Zoll.) Müll.Arg. - PT96-686 (SINU)
Macaranga tanarius (L.) Müll.Arg. - PT96-663 (SINU)
Macaranga triloba (Blume) Müll.Arg. - I.M.Turner PT23 (SINU)
Mallotus penangensis Müll.Arg. - PT96-147 (SINU)
Mallotus philippensis (Lam.) Müll.Arg. - PT96-681 (SINU)
Mallotus oblongifolius (Miq.) Müll.Arg. - PT96-466 (SINU)
Mallotus subcuneatus (Gage) Airy Shaw - I.M.Turner PT105 (SINU)
Melanolepis multiglandulosa (Reinw. *ex* Blume) Rchb.*f.* & Zoll. - A. Zainudin AZ 5813 (UKMB)
Micrococca mercurialis (L.) Benth. - PT96-30 (SINU)
Phyllanthus amarus Schumach. & Thonn. - PT96-151 (SINU)
Phyllanthus debilis Klein *ex* Willd. - PT96-655 (SINU)
Phyllanthus urinaria L. - PT96-640 (SINU)
c *Ricinus communis* L. - PT96-367 (SINU)
Sauropus androgynus (L.) Merr. - PT96-84 (SINU)
Suregada multiflora (Juss.) Baill. - PT96-347 (SINU)
Trigonostemon longifolius Baill. - PT96-109 (SINU)

Fagaceae

Castanopsis megacarpa Gamble - F.S.P. Ng, FRI 5087 (KEP)
Castanopsis inermis (Lindl. *ex* Wall.) Benth. & Hook.*f.* - Mohd. Yasin bin Aboo, KEP 70926 (KEP)
Lithocarpus bancanus (Scheff.) Rehder - A. Zainudin AZ 5923 (UKMB)

Flacourtiaceae

Casearia grewiifolia Vent. - I.H. Burkill S.F.N. 871 (SING)
c *Flacourtia jangomas* (Lour.) Raeusch. - I.H. Burkill *s.n.*, June 1915 (SING)
Flacourtia rukam Zoll. & Moritzi - A. Zainudin AZ 5782 (UKMB)
Hemiscolopia trimera (Boerl.) Slooten - PT96-443 (SINU)

Flagellariaceae

Flagellaria indica L. - PT96-271 (SINU)

Gesneriaceae

Didymocarpus antirrhinoides A. Weber - Strugnell KEP 70932 (KEP)
Didymocarpus tiumanicus (Ridl.) B.L. Burtt - PT96-619 (SINU)

Gnetaceae

c *Gnetum gnemon* L. - I.H. Burkill S.F.N. 964 (SING)
Gnetum macrostachyum Hook.*f.* - PT96-393 (SINU)

Goodeniaceae

Scaevola taccada (Gaertn.) Roxb. - PT96-44 (SINU)

Gramineae

Acroceras tonkinense (Balansa) C.E. Hubb. *ex* Bor - I.M.Turner PT72 (SINU)
c *Bambusa vulgaris* Schrad. *ex* Wendl. '*vittata*' - A. Zainudin AZ 5797 (UKMB)
c *Bambusa vulgaris* Schrad. *ex* Wendl. var. *vulgaris* - A. Zainudin AZ 5969 (UKMB)

Bothriochloa bladhii (Retz.) S.T. Blake - PT96-675 (SINU)
Centotheca lappacea (L.) Desv. - PT96-490 (SINU)
Chrysopogon aciculatus (Retz.) Trin. - PT96-149 (SINU)
Cyrtococcum accrescens (Trin.) Stapf - I.H. Burkill S.F.N. 913 (SING)
Dactyloctenium aegyptium (L.) Willd. - PT96-263 (SINU)
Dendrocalamus hirtellus Ridl. - I.H. Burkill S.F.N. 909 (SING)
Digitaria setigera Roem. & Schult. - PT96-602 (SINU)
Eleusine indica (L.) Gaertn. - PT96-143 (SINU)
Eragrostis amabilis (L.) Wight & Arn. *ex* Hook. & Arn. - PT96-152 (SINU)
Eragrostis cumingii Steud. - I.M.Turner PT74 (SINU)
Imperata cylindrica (L.) P. Beauv. - PT96-150 (SINU)
Ischaemum muticum L. - PT96-144 (SINU)
Miscanthus floridulus (Labill.) Warb. *ex* K. Schum. - I.M.Turner & D.J.Metcalfe PT89 (SINU)
Mnesithea glandulosa (Trin.) de Koning & Sosef - PT96-674 (SINU)
Oplismenus compositus (L.) P.Beauv. - PT96-467 (SINU)
Panicum sarmentosum Roxb. - PT96-473 (SINU)
Paspalum conjugatum Berg. - I.M.Turner PT113 (SINU)
Pennisetum polystachion (L.) Schult. - A. Zainudin AZ 3246 (UKMB)
Pogonatherum crinitum (Thunb. ex Murr.) Kunth - PT96-118 (SINU)
Schizostachyum jaculans Holttum - A. Zainudin AZ5817 (UKMB)
Setaria geniculata (Lam.) P. Beauv. - PT96-223 (SINU)
Sporobolus indicus (L.) R.Br. var. *flaccidus* (Roem. & Schult.) Veldkamp - I.H. Burkill S.F.N. 925 (SING)
Thuarea involuta (G. Forst.) R.Br. *ex* Roem. & Schult. - PT96-212 (SINU)
Urochloa paspaloides Presl - A. Zainudin AZ 5952 (UKMB)
Zoysia matrella (L.) Merr. - PT96-90 (SINU)

Guttiferae

Calophyllum depressinervosum M.R. Hend. & Wyatt-Sm. - A. ZainudinAZ 5845 (UKMB)
Calophyllum ferrugineum Ridl. - PT96-289 (SINU)
Calophyllum flavoramulum M.R. Hend. & Wyatt-Sm. - A. Zainudin AZ 5843 (UKMB)
Calophyllum inophyllum L. - PT96-167 (SINU)
Calophyllum pulcherrimum Wall. *ex* Choisy - KEP 70936 (KEP)
Cratoxylon cochinchinense (Lour.) Blume - A Zainudin AZ 5830 (UKMB)
Garcinia atroviridis Griff. *ex* T. Anderson - A. Zainudin AZ 5854 (UKMB)
Garcinia eugeniifolia Wall. *ex* T. Anderson - A. Zainudin AZ 5803 (UKMB)
Garcinia griffithii T. Anderson - Samsuri 63 (SINU)
Garcinia hombroniana Pierre - PT96-232 (SINU)
Garcinia nervosa Miq. - I.H. Burkill S.F.N. 887 (SING)
Garcinia nigrolineata Planch. *ex* T. Anderson - A. Zainudin AZ 5897 (UKMB)
Mesua aff. assamica (King & Prain) Kosterm. - F.S.P. Ng, FRI 5088 (KEP)

Heliconiaceae

c *Heliconia psittacorum* L.*f.* - A. Zainudin AZ 5793 (UKMB)

Hernandiaceae

Hernandia nymphaeifolia (Presl) Kubitski

- J. Feilding 4007, 1892 (SING)

Hydrocharitaceae

Thallassia hemprichii (Ehrenb.) Asch. - I.H. Burkill S.F.N. 900 (SING)

Hypoxidaceae

Molineria latifolia (Dryand.) Herb. - PT96-134 (SINU)

Icacinaceae

Phytocrene bracteata Wall. - I.H. Burkill S.F.N. 902 (SING)

Ixonanthaceae

Ixonanthes icosandra Jack - A. Zainudin AZ 5868 (UKMB)

Ixonanthes reticulata Jack - A. Zainudin AZ 3252 (UKMB)

Labiatae

c *Leonotis nepetifolia* (L.) R.Br. - PT96-18 (SINU)

Leucas zeylanica (L.) R.Br. - PT96-27 (SINU)

Ocimum basilicum L. - PT96-13 (SINU)

Ocimum tenuiflorum L. - PT96-37 (SINU)

Lauraceae

Actinodaphne ?montana Gamble - J. Sinclair, S.F.N. 40290 (SING)

Beilschmiedia kunstleri Gamble - A. Zainudin AZ 5915 (UKMB)

Cassytha filiformis L. - PT96-47 (SINU)

Cinnamomum cf. *altissimum* Kostermans - I.M.Turner PT64 (SINU)

Neolitsea zeylanica (Nees) Merr. - PT96-527 (SINU)

Lecythidaceae

Barringtonia asiatica (L.) Kurz - PT96-183 (SINU)

Barringtonia macrostachya (Jack) Kurz - I.H. Burkill S.F.N. 929 (SING)

Leeaceae

Leea indica (Burm.*f.*) Merr. - I.H. Burkill S.F.N. 920 (SING)

Leguminosae

Abrus precatorius L. - PT96-177 (SINU)

Adenanthera malayana Kosterm. - F.S.P. Ng, FRI 5072 (KEP)

Adenanthera pavonina L. - PT96-349 (SINU)

Archidendron ellipticum (Blume) I.C. Nielsen - A. Zainudin AZ 5788 (UKMB)

Bauhinia integrifolia Roxb. ssp. *integrifolia* - I.H. Burkill S.F.N. 951 (SING)

Callerya atropurpurea (Wall.) Schot - A. Zainudin AZ 5842 (UKMB)

Canavalia cathartica Thouars - PT96-322 (SINU)

Canavalia rosea (Sw.) DC. - A. Zainudin AZ 5825 (UKMB)

Crotalaria pallida Aiton - PT96-79 (SINU)

Crotalaria retusa L. - A. Zainudin AZ 5895 (UKMB)

Cynometra ramiflora L. - PT96-652 (SINU)

Dalbergia candenatensis (Dennst.) Prain - J. Feilding *s.n.*, Nov. 1892 (SING)

Dendrolobium umbellatum (L.) Benth. - PT96-336 (SINU)

Derris trifoliata Lour. - PT96-387 (SINU)

Erythrina fusca Lour. - PT96-292 (SINU)

Erythrina variegata L. - PT96-209 (SINU)

Intsia bijuga (Colebr.) Kuntze - I.H. Burkill., S.F.N. 891 (SING)

Koompassia malaccensis Maing. ex Benth. - Mohd. Yasin bin Aboo, KEP 70927 (KEP)

Lucaena leucocephala (Lam.) de Wit - PT96-10 (SINU)

Mimosa pudica L. - PT96-397 (SINU)

Peltophorum pterocarpum (DC.) K. Heyne - PT96-220 (SINU)

Pongamia pinnata (L.) Pierre - PT96-319 (SINU)

c *Saraca indica* L. - A. Zainudin AZ 5806 (UKMB)
Serianthes grandiflora Benth. - PT96-273 (SINU)
Senna alata (L.) Roxb. - A. Zainudin AZ 5815 (UKMB)
c *Senna fruticosa* (Mill.) Irwin & Barneby - PT96-3 (SINU)
Senna tora (L.) Roxb. - PT96-60 (SINU)
Sindora echinocalyx (Benth.) Prain - I.H. Burkill S.F.N. 896 (SING)
Sophora tomentosa L. - PT96-327 (SINU)
c *Tamarindus indica* L. - PT96-362 (SINU)
Tephrosia noctiflora Bojer *ex* Baker - PT96-488 (SINU)
Vigna marina (Burm.) Merr. - I.H. Burkill S.F.N. 892 (SING)
c *Vigna radiata* (L.) R. Wilczek - PT96-647 (SINU)

Loranthaceae

Dendrophthoe pentandra (L.) Miq. - PT96-633 (SINU)

Lythraceae

c *Lawsonia inermis* L. - PT96-43 (SINU)
Pemphis acidula J.R. Forst. & G. Forst. - PT96-169 (SINU)
Sonneratia alba J.J.Sm. - PT96-210 (SINU)

Malvaceae

c *Abelmoschus moschatus* Medik. - PT96-670 (SINU)
Abutilon indicum (L.) Sweet - A. Zainudin AZ 3239 (UKMB)
c *Hibiscus rosa-sinensis* L. - PT96-38 (SINU)
Hibiscus tiliaceus L. - I.H. Burkill S.F.N. 893 (SINU)
c *Malvaviscus penduliflorus* DC. - PT96-82 (SINU)
Sida rhombifolia L. - PT96-80 (SINU)
Thespesia populnea (L.) Sol. *ex* Corrêa - PT96-196 (SINU)
Urena lobata L. - PT96-621 (SINU)

Marantaceae

Donax grandis (Miq.) K. Schum. - PT96-122 (SINU)
c *Maranta arundinacea* L. - A. Zainudin AZ 5808 (UKMB)

Melastomataceae

Clidemia hirta (L.) D. Don - PT96-69 (SINU)
Melastoma malabathricum L. - PT96-323 (SINU)
Memecylon campanulatum C.B. Clarke - A. Zainudin AZ 3226 (UKMB)
Memecylon edule Roxb. - PT96-601 (SINU)
Memecylon lilacinum Zoll. & Moritzi - I.H. Burkill S.F.N. 903 (SING)
Pachycentria constricta (Blume) Blume - PT96-500 (SINU)
Pternandra echinata Jack - I.H. Burkill *s.n.*, June 1915 (SINU)

Meliaceae

c *Lansium domesticum* Corrêa - PT96-2 (SINU)
c *Melia azederach* L. - PT96-667 (SINU)
Xylocarpus granatum J. König - PT96-304 (SINU)
Xylocarpus rumphii (Kostel.) Mabb. - PT96-239 (SINU)

Menispermaceae

Cocculus orbiculatus (L.) DC. - PT96-245 (SINU)
Fibraurea tinctoria Lour. - PT96-414 (SINU)
Hypserpa nitida Miers - I.H. Burkill S.F.N. 880 (SING)
Pericampylus glaucus (Lam.) Merr. - PT96-494 (SINU)
Stephania capitata (Blume) Spreng. - PT96-280 (SINU)
c *Tinospora crispa* (L.) Hook.*f.* & Thomson - PT96-420 (SINU)

Moraceae

Artocarpus dadah Miq. - A. Zainudin AZ 5925 (UKMB)
Artocarpus hispidus F.M. Jarrett - A. Zainudin AZ 5846 (UKMB)
Artocarpus lanceifolius Roxb. - J. Sinclair s.n., May 1954 (SING)
Artocarpus rigidus Blume - A. Zainudin AZ 5863 (UKMB)
Ficus consociata Blume var. *murtoni* King - I.M.Turner PT52 (SINU)
Ficus drupacea Thunb. - PT96-422 (SINU)
Ficus globosa Blume - PT96-646 (SINU)
Ficus grossularioides Burm.*f.* - I.M.Turner PT81 (SINU)
Ficus hispida L.*f.* - PT96-330 (SINU)
Ficus microcarpa L.*f.* - PT96-355 (SINU)
Ficus scortechinii King - I.H. Burkill S.F.N. 954 (SING)
Ficus subcordata Blume - PT96-348 (SINU)
Ficus superba (Miq.) Miq. - PT96-368 (SINU)
Ficus tinctoria G. Forst. ssp. *gibbosa* (Blume) Corner - PT96-292 (SINU)
Ficus vasculosa Wall. *ex* Miq. - A. Zainudin AZ 5962 (UKMB)
Parartocarpus ?bracteatus (King) Becc. - F.S.P. Ng FRI 5076 (KEP)
Streblus ilicifolius (Vidal) Corner - I.H. Burkill S.F.N. 904 (SING)

Musaceae

Musa acuminata Colla ssp. *malaccensis* (Ridl.) N.W. Simmonds - PT96-146 (SINU)

Myristicaceae

Gymnacranthera forbesii (King) Warb. - A. Zainudin AZ 5902 (UKMB)
Horsfieldia irya (Gaertn.) Warb. - A. Zainudin AZ 5896 (UKMB)
Horsfieldia polyspherula (Hook.*f.*) J. Sinclair - J. Sinclair, S.F.N. 40288 (SING)
Horsfieldia tomentosa Warb. - A. Zainudin AZ 5847 (UKMB)
Knema communis J. Sinclair - A. Zainudin AZ 5926 (UKMB)
Knema hookeriana (Wall. *ex* Hook.*f.* & Thomson) Warb. - A. Zainudin AZ 5807 (UKMB)
Knema malayana Warb. - PT96-244 (SINU)
Knema scortechinii (King) J. Sinclair - J. Sinclair, S.F.N. 40287 (SING)
c *Myristica fragrans* Houtt. - PT96-66 (SINU)

Myrsinaceae

Aegiceras corniculatum (L.) Blanco - PT96-181 (SINU)
Ardisia elliptica Thunb. - I.H. Burkill S.F.N. 852 (SING)
Ardisia oxyphylla Wall. ex DC. - A. Zainudin AZ 5857 (UKMB)
Embelia ribes Burm. - A. Zainudin AZ 5908 (UKMB)
Labisia pumila (Blume) Fern.-Vill. - PT96-467 (SINU)
Maesa ramentacea Wall. *ex* Roxb. - PT96-498 (SINU)
Rapanea porteriana Wall. *ex* A.DC. - I.M.Turner PT66 (SINU)

Myrtaceae

c *Psidium guajava* L. - PT96-260 (SINU)
Rhodamnia cinerea Jack - A. Zainudin AZ 5867 (UKMB)
c *Syzygium aromaticum* (L.) Merr. & L.M. Perry - PT96-489 (SINU)
Syzygium grande (Wight) Walp. - PT96-250 (SINU)
c *Syzygium malaccense* (L.) Merr. & L.M. Perry - PT96-622 (SINU)
Syzygium pauper (Ridl.) I.M. Turner - I.H. Burkill S.F.N. 939 (SING)
Syzygium pendens (Duthie) I.M. Turner - D.J.Metcalfe & J.W.H.Yong PT90 (SINU)

Syzygium pycnanthum Merr. & L.M. Perry - I.H. Burkill S.F.N. 940 (SINU)
c *Syzygium samarangense* (Blume) Merr. & L.M. Perry - PT96-117 (SINU)

Nyctaginaceae
Boerhavia diffusa L. - PT96-141 (SINU)
c *Mirabilis jalapa* L. - PT96-28 (SINU)

Ochnaceae
Campylospermum serratum (Gaertn.) Bittrich & M.C.E. Amaral - J. Feilding *s.n.*, 27 Oct. 1892 (SING)

Olacaceae
Strombosia javanica Blume - I.H. Burkill S.F.N. 952 (SING)
Ximenia americana L. - I.H. Burkill S.F.N. 884 (SING)

Oleaceae
Olea brachiata (Lour.) Merr. - A. Zainudin AZ 3257 (UKMB)

Opiliaceae
Cansjera rheedii J.F. Gmel. - J. Feilding *s.n.*, 27 Oct. 1892 (SING)
Champereia manillana (Blume) Merr. - A. Zainudin AZ 5832 (UKMB)

Orchidaceae
Aerides odorata Lour. - PT96-502 (SINU)
Anoectochilus geniculatus Ridl. - PT96-285 (SINU)
Bulbophyllum vaginatum (Lindl.) Rchb.*f.* - PT96-228 (SINU)
Corymborkis veratrifolia (Reinw.) Blume - H.T.W.Tan PT8 (SINU)
Cymbidium atropurpureum (Lindl.) Rolfe - A. Zainudin AZ 5885 (UKMB)
Cymbidium finlaysonianum Lindl. - PT96-188 (SINU)
Dendrobium crumenatum Sw. - PT96-333 (SINU)
Eulophia spectabilis (Dennst.) Suresh - PT96-301 (SINU)

Oxalidaceae
c *Averrhoea bilimbi* L. - PT96-57 (SINU)
c *Averrhoa carambola* L. - PT96-23 (SINU)
Oxalis barrelieri L. - PT96-404 (SINU)

Palmae
Arenga westerhoutii Griff. - A. Zainudin AZ 5802 (UKMB)
Calamus javensis Blume - A. Zainudin AZ 5800 (UKMB)
Caryota mitis Lour. - PT96-335 (SINU)
Daemonorops lewisiana (Griff.) Mart. - I.H. Burkill S.F.N. 866 (SING)
Daemonorops melanochaetes Blume - A. Zainudin AZ 5920 (UKMB)
Korthalsia rigida Blume - J.W.H.Yong PT16 (SINU)
Korthalsia rostrata Blume - A. Zainudin AZ 5917 (UKMB)
Licuala ferruginea Becc. - PT96-635 (SINU)
Licuala spinosa Wurmb - A. Zainudin AZ 5872 (UKMB)
Nypa fruticans Wurmb - PT96-274 (SINU)
Orania sylvicola (Griff.) H.E. Moore - PT96-161 (SINU)
Plectocomia elongata Mart. *ex* Blume - I.M.Turner PT63 (SINU)

Pandanaceae
Freycinetia sumatrana Hemsl. - I.M.Turner PT39 (SINU)
c *Pandanus amaryllifolius* Roxb. - PT96-409 (SINU)
Pandanus dubius Spreng. - PT96-268 (SINU)
Pandanus lais Kurz - I.H. Burkill S.F.N. 957 (SING)
Pandanus c.f. *longicaudatus* Holttum & H. St.John - J.W.H.Yong PT61 (SINU)
Pandanus odoratissimus L.*f.* - PT96-201 (SINU)

Passifloraceae
Adenia macrophylla (Blume) Koord. var.

macrophylla - I.M.Turner PT69 (SINU)
Passiflora foetida L. - PT96-11 (SINU)
Passiflora laurifolia L. - PT96-626 (SINU)

Pedaliaceae
Sesamum orientale L. - PT96-187 (SINU)

Phormiaceae
Dianella ensifolia (L.) DC. - PT96-408 (SINU)

Piperaceae
Piper caninum Blume - D.J.Metcalfe PT122 (SINU)
Piper pedicellosum Wall. - A. Zainudin AZ 5789 (UKMB)
Piper protractum C. DC. - M.C.Lim PT29 (SINU)
c *Piper sarmentosum* Roxb. - PT96-24 (SINU)

Pittosporaceae
Pittosporum ferrugineum W.T. Aiton - PT96-48 (SINU)

Podocarpaceae
Podocarpus polystachyus R.Br. *ex* Endl. - PT96-193 (SINU)

Polgalaceae
Polygala paniculata L. - PT96-156 (SINU)
Xanthophyllum affine Korth. *ex* Miq. - F.S.P. Ng, FRI 5085 (KEP)
Xanthophyllum amoenum Chodat - A. Zainudin AZ 5914 (UKMB)
Xanthophyllum vitellinum (Blume) Dietr. - A. Zainudin AZ 5918 (UKMB)

Portulacaceae
Portulaca oleracea L. - PT96-215 (SINU)

Punicaceae
c *Punica granatum* L. - PT96-46 (SINU)

Ranunculaceae
Clematis smilacifolia Wall. - I.H. Burkill S.F.N. 857 (SING)

Rhamnaceae
Colubrina asiatica L. *ex* Brongn. - I.H. Burkill S.F.N. 894 (SING)

Rhizophoraceae
Bruguiera cylindrica (L.) Blume - PT96-198 (SINU)
Bruguiera gymnorhiza (L.) Lam. ex Savigny - I.H. Burkill S.F.N. 953 (SING)
Bruguiera sexangula (Lour.) Poir. - PT96-643 (SINU)
Ceriops decandra (Griff.) W. Theob. - PT96-454 (SINU)
Ceriops tagal (Pers.) C.B. Rob. - PT96-206 (SINU)
Rhizophora apiculata Blume - PT96-297 (SINU)
Rhizophora mucronata Lam. - PT96-211 (SINU)
Rhizophora stylosa Griff. - PT96-453 (SINU)

Rosaceae
Rubus moluccanus L. var. *angulosus* Kalkman - I.H. Burkill S.F.N. 860 (SING)

Rubiaceae
Aidia densiflora (Wall.) Masam. - I.H. Burkill S.F.N. 870 (SING)
Borreria laevicaulis (Miq.) Ridl. - A. Zainudin AZ 5934 (UKMB)
Chassalia curviflora (Wall.) Thwaites - J.W.H.Yong PT106 (SINU)
c *Gardenia augusta* (L.) Merr. - PT96-403 (SINU)
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Hedyotis capitellata Wall. ex G. Don - PT96-616 (SINU)

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Hydnophytum formicarum Jack - I.H. Burkill S.F.N. 869 (SING)
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Ixora lobbii King & Gamble - J. Feilding *s.n.*, Oct. 1892 (SING)
Ixora pendula Jack - A. Zainudin AZ 3225 (UKMB)
Lasianthus cyanocarpus Jack - PT96-668 (SINU)
Morinda citrifolia L. - PT96-425 (SINU)
Morinda elliptica (Hook.*f.*) Ridl. - A. Zainudin AZ 3217 (UKMB)
Morinda umbellata L. - PT96-432 (SINU)
Ophiorrhiza discolor R.Br. - H.T.W.Tan PT32 (SINU)
Pavetta naucleiflora R. Br. *ex* G. Don - I.H. Burkill S.F.N. 868 (SING)
Psychotria brachybotrys Ridl. - A. Zainudin AZ 5828 (UKMB)
Psychotria sarmentosa Blume - PT96-493 (SINU)
Scyphiphora hydrophyllacea C.F. Gaertn. - PT96-192 (SINU)
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Timonius compressicaulis (Miq.) Boerl. - I.H. Burkill S.F.N. 854 (SING)
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Nephelium juglandifolium Blume - A. Zainudin AZ 5848 (UKMB)
Pometia pinnata J.R. Forst. & G. Forst. - Mohd. Yasin bin Aboo. KEP 70929 (KEP)

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Manilkara kauki (L.) Dubard - I.H. Burkill S.F.N. 942 (SING)
c *Manilkara zapota* (L.) Royen - PT96-20 (SINU)
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Payena lucida A. DC. - F.S.P. Ng FRI 5082 (KEP)
Pouteria linggensis (Burck) Baehni - I.H. Burkill S.F.N. 876 (SING)
Pouteria maingayi (C.B. Clarke) Baehni - F.S.P. Ng. FRI 5079 (KEP)
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Cayratia japonica (Thunb.) Gagnep. - PT96-269 (SINU)
Cayratia trifolia (L.) Domin - F.S.P. Ng, FRI 5101 (SING)
Cissus hastata Miq. - PT96-363 (SINU)
Cissus repens Lam. - PT96-358 (SINU)

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c *Alpinia galanga* (L.) Sw. - I.H. Burkill S.F.N. 861 (SING)
?*Amomum cephalotes* Ridl. - I.H. Burkill S.F.N. 882 (SING)
Amomum testaceum Ridl. - PT96-417 (SINU)
Amomum xanthophlebium Baker - PT96-507 (SINU)

Tree Flora of Sabah and Sarawak edited by E. Soepadmo and K.M. Wong, jointly published by the Sabah Forestry Department, Forest Research Institute Malaysia and the Sarawak Forestry Department. Vol 1 (1995) Ll + 513 pp, Vol 2 (1996) x + 443 pp.

The Tree Flora of Sabah and Sarawak is an ambitious project, some might even say 'mission impossible'. The aim is to produce a flora of the trees, woody plants of at least 5 m tall and 10 cm dbh, of the two Bornean states of Malaysia. This, it is estimated, will be enough to fill eight volumes, each covering some 300-400 species; and, what is more, it is proposed to complete the whole undertaking in ten years.

Two volumes have been published so far, and they are simply magnificent. It is always possible to find something to criticise, and I will indulge in the reviewer's liberty to nitpick below, but in general the first two volumes of the flora are excellent in every department. The quality of production is outstanding, the standard of the taxonomic treatments excellent, the drawings wonderful.

The first volume starts with three introductory chapters. These are: an overview of the background to the Tree Flora of Sabah and Sarawak Project by Professor E. Soepadmo, a brief history of plant collecting and floristic accounts of Borneo by Dr Wong Khoon Meng, and an essay on the biogeography and ecology of northern Borneo by Professor Peter Ashton. There follow accounts of 31 families (Acer., Alangi., Anisophylle., Araucari., Bignoni., Burser., Cappar., Celastr., Chrysoblan., Clethr., Connar., Corn., Datisc., Goodeni., Hyperic., Illici., Jugland., Monimi., Nyss., Ochn., Olac., Oxalid., Pittospor., Rhamn., Rhizophor., Rut., Simaroub., Sonnerati., Staphyle., Styr. & Trigoni.). Volume Two includes 23 families (Anacardi., Boragin., Caprifoli., Casuarin., Chloranth., Crypteroni., Ctenolophon., Daphniphyll., Epacrid., Erythroxyl., Ixonanth., Lee., Logani., Lythr., Malv., Myric., Nyctagin., Santal., Sapind., Scyphostegi., Tetramerist., Ulm. & Winter.). The accounts are contributed by many authors, including the Director of the Royal Botanic Gardens Kew and many junior staff members of Malaysian Herbaria. The project workhorse is clearly Mr K.M. Kochummen who has provided the treatments of most of the larger families included thus far. The family accounts include a key to all genera occurring in Sabah and Sarawak, followed by more detailed entries for genera that include trees, with full keys and species descriptions of arborescent taxa. This is a proper flora and not merely a manual for foresters, so major synonyms and typification are given, but the inclusion of one plate for each genus containing trees, the use of not-overly-technical language and strict adherence to alphabetical arrangement of taxa will help to make the flora more accessible to readers who are not taxonomists.

The preparatory work for the flora has led to the discovery of many new species, 39 in volume two alone. Also Wong and Sugau, in their treatment of the Loganiaceae employ a much narrower species concept in *Fagraea* than Leenhouts (1962) did in his account for Flora Malesiana. In a precursory paper, Wong and Sugau (1996) have divided Leenhouts's *Fagraea fragrans, F. ceilanica* and *F. elliptica* and *F. racemosa* into many elements. The relative susceptibility of taxonomists to see discontinuity or intergradation will frequently lead to different treatments of groups exhibiting complex variation like *Fagraea.* Users of the *Tree Flora of Sabah and Sarawak* will have the opportunity to test whether Wong and Sugau's species are justified.

My only major complaint about the flora is the frequent omission of any discussion about the taxonomy employed. In the introduction it is stated that Brummit (1993) is the main guide to familial and generic circumscription, yet the two volumes contain instances where Brummit has not been followed e.g. the maintenance of the Sonneratiaceae and the Hypericaceae, the inclusion of *Irvingia* and *Ailanthus* in the Simaroubaceae, and the recognition of *Neckera* and *Roureopsis,* all of which I felt warranted more discussion. Similarly the use of *Scaevola sericea* over *Scaevola taccada* needed reference to the literature on this major nomenclatural controversy. I believe the correct name for *Scleropyrum wallichianum is Scleropyrum pentandrum* (Dennst.) Mabb. (Mabberley 1977) and that William Theobold made the combination *Ceriops decandra* well before Ding Hou (Mabberley 1985) .

These are minor quibbles. The Tree Flora of Sabah and Sarawak is excellent and should be included in any library (personal or institutional) which purports to cover the flora of Southeast Asia. The team that has produced the two volumes deserves hearty congratulations for what has been achieved, and encouragement to face the challenges ahead.

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Ian Turner
School of Biological Sciences
National University of Singapore

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Literature citations: Citations in the text should take the form: King and Chan (1964). If several papers by the same author in the same year are cited, they should be lettered in sequence (1964a), (1964b), etc. When papers are by three or more authors they should be cited as e.g., Geesink *et al.* (1981). All references must be placed in alphabetic order according to the surname of the (first) author and the journal title be given in full, as in the following example:

> Stone, B.C. 1994. Additional notes on the genus *Glycosmis* Correa (Rutaceae). *Gardens' Bulletin Singapore. 46: 113-119.*

References to books and monographs should be cited according to the following form:

> Ridley, H.N. 1930. *The Dispersal of Plants Throughout the World.* L.Reeve, Ashford, Kent.

For literature citations in taxonomic papers the following style is required:

> *Medinilla alternifolia* Blume, Mus. Bot. Lugd.-Bat. I:2 (1849) 19.
> *Sterculia acuminatissima* Merr., Philip. J. Sci. 21 (1922) 524.

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Biodiversity in the Nature Reserves of Singapore

Edited by
Lena Chan
National Parks Board
Richard T. Corlett
University of Hong Kong

Proceedings of the Nature Reserves Survey Seminar,
Singapore, December 1997

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PREFACE

Singapore, despite having a total area of only 648 sq. kilometre, inherited a rich natural indigenous legacy including over two thousand plant species, eighty mammal species, a hundred bird species, and forty freshwater fish species. The Nature Reserves, comprising Bukit Timah Nature Reserve and Central Catchment Nature Reserve, are situated in the centre of Singapore and constitute the largest remaining naturally vegetated area. Although the biodiversity of Bukit Timah Nature Reserve has been well-studied, prior to the Nature Reserves Survey, documentation relied heavily on *ad hoc*, sporadic, and irregular surveys carried out by individual researchers or groups with interest in specific taxonomic categories. In contrast, the Central Catchment Nature Reserve was poorly surveyed before this project.

By the early 1990s, it was apparent that a concerted effort at scientifically documenting the biodiversity of the largest conservation area in Singapore was long overdue. In 1991, a physical and biological survey of the Nature Reserves was proposed with the following broad targets:

1. Geophysical survey on drainage, topography and soil of the Reserves; and
2. Detailed flora and fauna surveys and identification of specimens.

The Singapore Government financed the physical survey while the cost of the biological survey was supported with funds provided by Lady Yuen Peng McNeice, patron of the Singapore Botanic Gardens and the Cheng Kim Loke Foundation. The project, co-ordinated by the Nature Conservation Branch of the National Parks Board, spanned from 1992 to 1997. It culminated in a seminar held in December 1997 where the participating researchers presented their findings.

New records of at least four mammals, two reptiles and three amphibians and the rediscovery of two reptiles and two amphibians that had not been sighted in the Nature Reserves for the past thirty years, amply confirm that the merits of a co-ordinated systematic survey.

The findings have already been put to good use. A Recreational Masterplan for the Nature Reserves has been formulated taking into account the distribution of sensitive species. Biological databases have been established for the taxonomic groups surveyed during this project and this will form the cornerstone of the proposed National Biodiversity Reference Centre. The information accumulated forms a reliable baseline for monitoring studies. There are many more projects in the pipeline that will utilise the biodiversity data collected, particularly in the field of nature conservation education.

This survey has indeed been a landmark in the history of nature

conservation in Singapore. It has amassed valuable data that should be made more accessible, to academics as well as the general public. To reach a wider audience and to provide a single permanent record for monitoring and future comparisons, much of the data collected during the survey and presented in the Nature Reserves Seminar has been compiled into this special issue of the Gardens' Bulletin.

The work carried out during the Nature Reserves Survey has laid a firm foundation from which Singapore could springboard into nature conservation initiatives in the New Millenium.

Dr. Tan Wee Kiat
Chief Executive Officer
National Parks Board
1 February 1999

ACKNOWLEDGEMENTS

The Nature Reserves Survey would not have been possible if not for the foresight of the Singapore Government and Lady Yuen Peng McNeice's ardent support for conservation. The generous financial support from Lady McNeice, the Cheng Kim Loke Foundation and the Singapore Government is gratefully acknowledged.

Dr. Leong Chee Chiew was instrumental in the initiation of this project and in subsequently steering its course. He has unstintingly stood by the project through thick and thin and we are very grateful for it.

The consultants, Mr. Wong Yew Kwan and Professor D. H. Murphy, contributed to the Nature Reserves Survey in many ways, far beyond their terms of reference.

For a survey spanning several years, particular credit must be given to several people who were responsible for the smooth running of the project. This list includes Ali Ibrahim, Sharon Chan, Chew Ping Ting, Cheryl Chia, Wendy Kan, Shirley Pottie, Saifuddin Suran, Tay Eng Pin, Robert Teo and Elspeth Waghorn.

It is impossible to name all the individuals who so magnanimously contributed their time or expertise to the survey work carried out on the diverse taxonomic groups. From the Nature Society (Singapore), the dedicated and exemplary work of the Vertebrate Group and the Bird Group is most appreciated. Many members from the Department of Biological Sciences, the Zoological Reference Collection and the Geography Department of the National University of Singapore participated actively in the project and many thanks go to them for their unwavering support and involvement. The number of weekends that Khew Sin Khoon and the Butterfly Watching and Research Group of the Nature Society (Singapore) had sacrificed in the documentation of butterfly biodiversity was numerous and their efforts are gratefully acknowledged. We are much richer in our knowledge of stick- and leaf-insect biodiversity entirely due to the single-minded devotion of Dr Francis Seow-Choen and his family to this interesting taxonomic group. The contribution of the National Institute of Education of the National Technological University is also acknowledged. We thank the Public Utilities Board and the Ministry of Defence for their unfailing assistance in transportation and logistic support.

The fieldwork was greatly facilitated by the staff members of the Nature Reserves Management Branch, especially the work of the rangers, the daily rated employees and the drivers. We sincerely thank Sharon Chan for her continuous and stalwart support in fieldwork co-ordination, a contribution that cannot be over-acknowledged.

Sharon Chan also played a pivotal role in the initiation and

organisation of the Nature Reserves Seminar and its success can largely be credited to her efforts. We also acknowledge the contributions of Nasir Abdullah, Rehan Yusoff, Tay Soon Lian and Sunia Corina Teo from the Nature Reserves Management Branch and all the other logistic support staff during the Nature Reserves Seminar. The co-ordinated efforts of Chew Ping Ting, Cheryl Chia and Saifuddin Suran of the Nature Conservation Branch ensured the smooth running of the seminar.

This special issue of the Gardens' Bulletin occupies an unique niche in the Nature Reserves Survey Project. Many people contributed to bringing this volume to fruition. In particular, we thank Chew Ping Ting and Cheryl Chia for the excellent production of the GIS maps and general [illegible]g. Our profoundest thanks must go to Cheryl Chia for her untiring amendment and editing of the numerous versions of the papers. Without Cheryl, the editorial work would have been more tedious and prolonged. Special thanks are due to Dr Ruth Kiew for her efficient assistance in the general editing of the papers. We would also like to thank Dr Ian Turner for his critical comments on some of the papers.

Finally, we thank Dr Tan Wee Kiat and Dr Chin See Chung for their unfailing support of the project, which kept the morale high.

To all the above-named and the many more unnamed contributors, we express our keenest appreciation for all the time, effort, support and dedication each and everyone gave to this mammoth task of documenting the biodiversity of Singapore. This volume stands as a testimony to their dedication to nature conservation.

Thank you, *Terima kasih, Xie xie* and *Nantri.*

Lena Chan & Richard Corlett
1 February 1999

Proceedings of the Nature Reserves Survey Seminar.
Gardens' Bulletin Singapore 49 (1997) 147–159.

The Vegetation in the Nature Reserves of Singapore

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Abstract

Singapore's native, non-coastal biota is almost entirely forest-dependent. Progressive deforestation during the nineteenth century reduced forest cover to isolated patches in a matrix of grassland. All primary forest patches outside the nature reserves were cleared but protection within the reserves has allowed the growth of secondary forest. The surviving primary forest patches are still distinct from the oldest secondary forest in their species diversity and structural complexity. The freshwater swamp forest at Nee Soon is also clearly distinct from the dryland primary forest. The highest conservation priority must be given to the primary forest remnants, which support most of the surviving flora, and to the older second. y forest. Non-forest areas within the reserves should be reforested.

Introduction

Vegetation forms the matrix in which both plants and animals live, as well as supplying the food on which most animals depend. In Singapore's continuously hot and wet climate, forest is the natural vegetation on almost all substrates. Corlett (1991a) estimated that mangrove forest made up 13% of the original forest area, freshwater swamp forest an additional 5%, and the remainder was lowland dipterocarp forest. Before human impact, permanent open sites would have been confined to coastal cliffs and sandy beaches. This basic fact has profound implications for understanding the biodiversity of modern Singapore: all native, non-coastal species of plants and animals are adapted to and, usually, dependent on forest, and are thus adversely affected by deforestation.

There is no evidence for significant forest clearance in the interior of the island before the nineteenth century, although coastal settlements have existed for centuries (Corlett, 1992a, 1992b). Most of the deforestation occurred in the period 1819–1900, after the foundation of the British colony resulted in a rapid rise in population. Much of the initial clearance of primary forest was for the cultivation of gambier (*Uncaria gambir*, Rubiaceae), which grows best on soil newly cleared of forest and needs a roughly equal area of forest to provide firewood for boiling the gambier leaves (Jackson, 1965). The gambier growers moved on when the soil and

firewood supplies were exhausted. The results of this "reckless, migratory cultivation" were described by Cantley (1884):

> Such Crown forests as remain uncut are widely distributed in isolated patches over the island. These forest patches or clumps are of various sizes, from half an acre or so to about 25 acres [10 ha], and of no particular shape; their distance from each other may average a quarter of a mile [0.4 km] though often exceeding a mile [1.6 km]. The interspace is generally waste grassland, which supports, as a rule, only strongly-growing grass known locally as "lalang" [*Imperata cylindrica*].

From 1884, many of the larger forest patches were included in forest reserves, but most of these were eventually abandoned (Corlett, 1995a). Primary forest remnants survived only in those areas that have received continuous protection, all of which are within the current nature reserves in the central part of the island. Here, the cessation of cultivation and control of grassland fires allowed the growth of secondary forest, which restored links between some of the remnant patches. Subsequently, however, the construction of reservoirs, roads and both recreational and military facilities has re-fragmented the forest area (Figure 1).

The vegetation of Singapore as a whole has been described by Corlett (1991a, 1992a). This paper concentrates on the vegetation of the current nature reserves.

Sources

Singapore has had more than a century of continuous botanical collecting activity. Checklists for the flora have been published by Ridley (1900), Keng (1990), Turner *et al.* (1990) and Turner (1993). New species continue to be added to a total which now stands at 2323 native species (Ali Ibrahim *et al.*, 1997). Corlett (1990, 1995b) recorded a total of 843 forest angiosperm species seen, collected or reported from Bukit Timah Nature Reserve since records began. Turner (1994) gives the total recorded forest vascular flora of Singapore as 1673 species (with 912 spp. at Bukit Timah Nature Reserve) and Turner *et al.* (1994) estimate that 1196 (71%) of these survive today, all but a few within the nature reserves. More than 700 vascular plant species have been recorded from freshwater swamp forest in Singapore but many of these were only known from areas which had been cleared (Turner *et al.*, 1996a). The many forest plots enumerated during the forest surveys described below cover a total of 20 ha, which is only about one

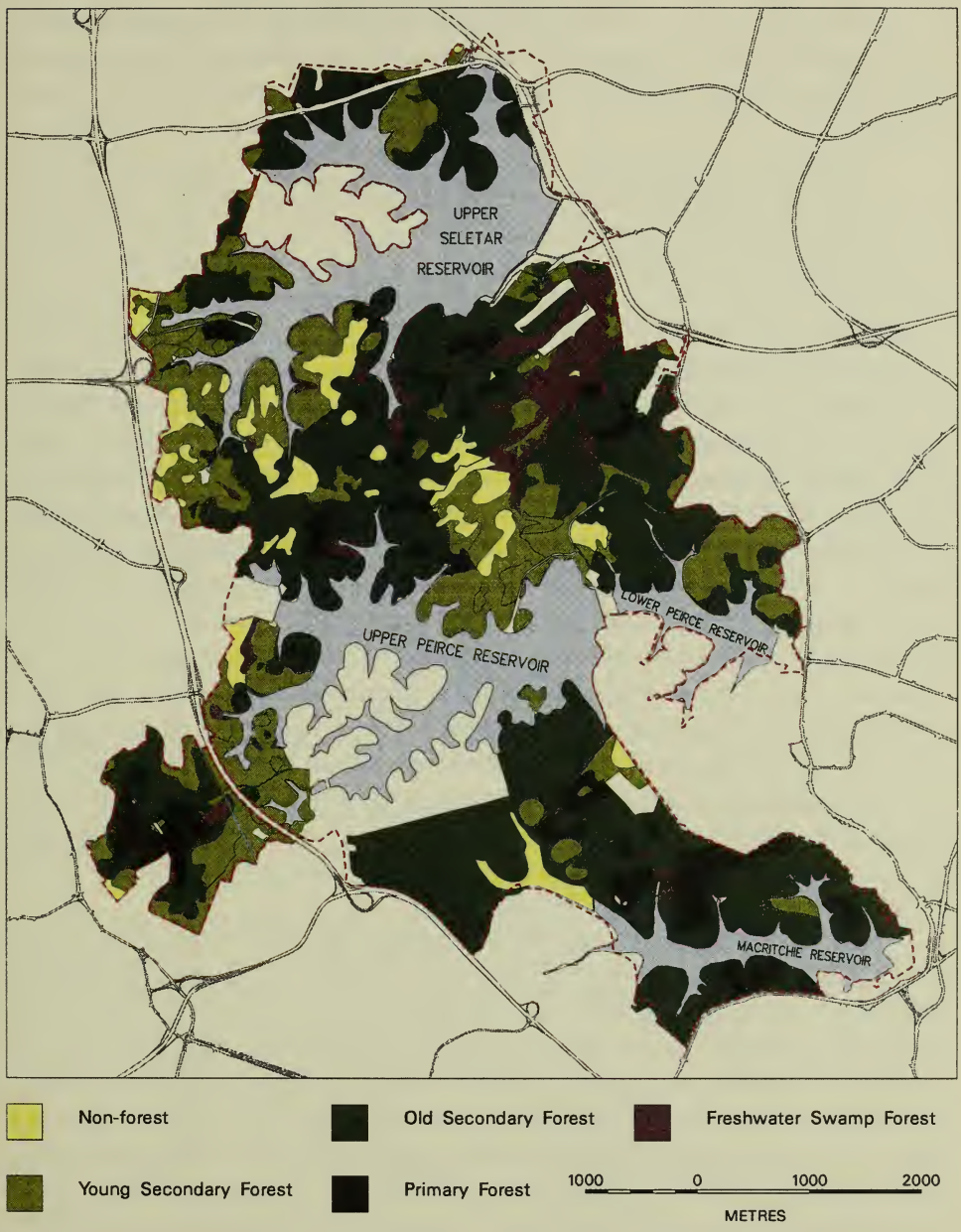

Figure 1. Map of the Nature Reserves showing the major vegetation types.

percent of the total forest area within the reserves. However, much of the rest of the reserve area has been sampled by collectors within the past century, with particular attention paid to previously under-collected parts of the Central Catchment Nature Reserves since 1992. Despite this, more species undoubtedly remain to be discovered and some currently believed to be extinct (Turner *et al.*, 1995) have been rediscovered (Kiew & Chan, in press).

Wee (1964) mapped the vegetation of the nature reserves from the 1955 aerial photographs, followed by field reconnaissance. He recognized five vegetation types: high forest (recognized only on Bukit Timah), regenerating high forest, regenerating swamp forest, *belukar tua* (old secondary forest), and *belukar muda* (young secondary forest, shrubland, grassland and fernland). Hill (1977) mapped the vegetation of the whole of Singapore, including the nature reserves, from aerial photographs. Within the reserves, he recognized five vegetation types: lowland rain forest, freshwater swamp forest, tall secondary forest (with crowns mainly >10 m high), low secondary forest (<10 m), and grass and scrub (including *Dicranopteris* fernlands). Wong *et al.* (1994), using 1990 aerial photographs, recognized four vegetation types within the Central Catchment Nature Reserve: Type 1, consisting of early successional vegetation with only scattered trees; Type 2, with many small-crowned trees 8–15 m tall; Type 3, with taller, larger-crowned trees; and Type 4, with some very large trees. These structural types were mapped in Turner *et al.* (1996b), who also compared this structural classification with a floristic ordination and classification of Wong *et al.*'s (1994) plot data. Metcalfe *et al.* (1998) classified the forest types in a 200 m x 200 m grid at Bukit Timah into four types: near-pristine forest with no visible signs of human disturbance (around 10% of the forest area), other primary forest (52%), old secondary forest (31%), and young secondary forest (7%).

The first quantitative vegetation studies within the area now covered by the reserves were done in 1933 by Corner, in a patch of primary freshwater swamp forest along the old Mandai Road (Corner, 1978). He enumerated slightly over a hectare of this forest, which was felled for an extension of Seletar Reservoir in 1940. Then, in the late 1950s, Gilliland and co-workers measured and identified all plants within three 1000 feet x 6 feet (305 x 2m) transects in the nature reserves: one in regenerating high forest south of MacRitchie Reservoir (Gilliland & Wantman, 1958), one in tall secondary forest adjacent to Lornie Road and the golf course (Gilliland, 1958), and one in younger secondary forest in the Mandai area (Gilliland & Mohd. Jabil, 1958). Gilliland named the three forest types the *Shorea/Agrostistachys* community, the *Rhodamnia/Champereia* community, and the *Eugenia/Arthrophyllum* community, respectively.

Wong (1987) enumerated all trees > 24 inches (61cm) girth at breast height (gbh) in twenty 0.4 acre (0.16 ha) clusters of four circular subplots located systematically on a grid at Bukit Timah Nature Reserve. Swan (1988) mapped, measured and identified all stems > 2 cm dbh in two 0.24 ha plots on Bukit Timah, in Fern Valley and Jungle Falls Valley, respectively. Corlett (1991b) measured and identified all stems > 2 cm dbh in fifteen 0.1 ha plots in tall secondary forest in the Central Catchment Nature Reserve. An additional five plots were located in primary forest remnants (Corlett, unpublished). Sim *et al.* (1992) included a 225 m^2 plot at Bukit Timah in a survey of *Adinandra* belukar in Singapore. In by far the biggest survey to date, Wong *et al.* (1994) measured and identified trees > 30 cm gbh in sixty-two 0.2 ha clusters of four circular subplots in the Central Catchment Nature Reserve and Turner *et al.* (1996c) enumerated herbaceous plants in 46 of these clusters. In 1993, the Center for Tropical Forest Science and the National Institute of Education, Nanyang Technological University, established a 2 ha permanent plot in the primary forest core of Bukit Timah Nature Reserve (LaFrankie *et al.*, 1996; Ercelawn *et al.*, 1998). All trees > 1 cm dbh have now been censused twice, in 1993 and 1995, allowing the assessment of short-term recruitment within the plot.

Vegetation

Dryland Primary Forest

All studies of the nature reserves have recognized a distinct forest type characterized by the presence of huge individual trees, including dipterocarps. It is likely that all the patches of this type were logged for timber and exploited for firewood before and, probably, to some extent, after protection. This exploitation seems to have been relatively light at Bukit Timah and may have been extremely heavy in some patches kept as firewood reserves for gambier plantations in the centre of the island. However, these distinctions have been largely obscured by a century or more of regeneration so it is now simplest and most informative to refer to all this forest as primary, i.e., forest which has never been completely cleared (Corlett, 1994). The continuity of forest occurrence on a site results in a richer flora than even the oldest secondary forests (Corlett, 1995c; Turner *et al.*, 1997). The total area of dryland primary forest in the Nature Reserves is approximately 192 ha, 80% of which is within the Central Catchment Nature Reserve.

Most of the dryland primary forest remnants in Singapore consist of lowland dipterocarp forest, with members of the family Dipterocarpaceae

(*Anisoptera, Dipterocarpus, Hopea, Shorea*) dominant among the large trees. The species composition in the Central Catchment Nature Reserve most closely matches the Red Meranti-Keruing forest type of Wyatt-Smith (1963, 1964). Most of the primary forest on Bukit Timah Hill can be distinguished as coastal hill dipterocarp forest by the dominance of *Shorea curtisii* and *Dipterocarpus caudatus* subsp. *penangianus* (Wong, 1987; Swan, 1988; LaFrankie *et al.,* 1996), but the flora is otherwise similar to that of the patches in the Central Catchment Nature Reserve. Other prominent large tree species in the dryland primary forest include several members of the Burseraceae, *Adenanthera bicolor (*Leguminosae), *Dyera costulata* (Apocynaceae), *Gluta wallichii* (Anacardiaceae), *Ixonanthes icosandra* (Ixonanthaceae), *Koompassia malaccensis* (Leguminosae) and *Mangifera griffithii* (Anacardiaceae). The major families of smaller trees and shrubs are the Annonaceae, Euphorbiaceae, Lauraceae, Myrtaceae and Rubiaceae. Woody climbers have been ignored in most plot surveys and undercollected in general. Rattans (spiny, climbing palms in the genera *Calamus, Daemonorops, Korthalsia* and *Plectocomia*) are particularly abundant at Bukit Timah and in some of the primary forest patches in the central catchment area. The other major families of large, woody climbers are the Rubiaceae (*Uncaria*), Annonaceae (*Artabotrys, Fissistigma*), Apocynaceae (*Leuconotis, Willughbeia*), Leguminosae (*Dalbergia, Derris, Entada, Spatholobus*) and Connaraceae (*Rourea*). Ferns and several families of monocotyledons dominate the herb flora, but herb diversity is low in Singapore's forests, and not strongly differentiated between types (Turner *et al.*, 1996c).

Primary Freshwater Swamp Forest

In all floristic surveys - and, for that matter, most faunistic surveys - the most distinctive forest type is the freshwater swamp forest at Nee Soon. This swamp system is extremely complex and we do not know enough to explain the patterns observed. Indeed, they are probably not explicable in terms of the present day environment, since the all-important water regime must have been drastically altered by changes both up and down stream of the existing remnants. Turner *et al.* (1996a) bring together current knowledge of the Nee Soon swamp forest and estimate the total area as about 87 ha. Swamp forest occurs in low-lying areas where the water table is close to the soil surface and the soil is usually rich in organic matter. Many of the most characteristic tree species produce striking stilt roots (e.g., *Palaquium xanthochymum,* Sapotaceae and *Xylopia fusca*, Annonaceae) and/or pneumatophores of various types (plank-like in *Lophopetalum multinervium*, Celastraceae) illustrated in Corner (1978),

presumably as an adaptation to this substrate and the periodic floods to which most of the forest is subject.

Secondary Forests

Secondary forest is the most extensive vegetation type in the Nature Reserves, covering a total area of about 1560 ha. Although different types of secondary forest often seem sharply distinct at their boundaries on the ground and in aerial photographs, ordination and classification techniques show that they are all part of a floristic continuum (Corlett, 1991b; Turner *et al.*, 1997). Most authors have interpreted this continuum as representing stages in successional development after the abandonment of cultivation. However, it is possible that much of the variation reflects degrees of site degradation, and that areas abandoned at the same time may have very different vegetation. Unfortunately, we cannot usually date the start of forest succession sufficiently accurately to test this hypothesis.

The strongest evidence against "time since abandonment" as the only determining factor is the striking persistence of some - but by no means all - of the patches of open, scrubby vegetation between a vegetation map based on 1955 aerial photographs (Wee, 1964) and the present day, 43 years later. The ground in these areas is typically covered in a dense growth of the fern *Dicranopteris linearis*, grasses or, occasionally, sedges. Trees, particularly *Adinandra dumosa* (Theaceae) and *Rhodamnia cinerea* (Myrtaceae), occur as scattered clumps and isolated individuals. Fire has undoubtedly been a factor in some cases, but soil factors or the inhibitory effects of a dense herbaceous ground cover may also be important. Whatever the explanation, these persistent open areas should not be seen as a model for the early stages of succession in areas now covered in tall secondary forest. For these latter areas, presumably on more fertile soils, the first stage of forest succession seems to have been the dense *Adinandra*-dominated forest, which can be seen today in a few places within the reserves and several areas outside (Corlett, 1991b; Sim *et al.*, 1992). Holttum (1954) reported that in 1930–40 "there were very large areas of dense, almost pure *Adinandra* forest" in the catchment area, although much of this was felled for use as poles just before and during the war. *Macaranga conifera* (Euphorbiaceae), while apparently not a normal component of this community, becomes prominent in regeneration after fire or cutting, presumably in response to the increased nutrient supply (Corlett, 1991b).

Structural and floristic classifications of the secondary forests within the reserves do not agree well (Turner *et al.*, 1996b, 1997) but most sites can be arranged along a successional gradient, whether or not this represents time since initiation of succession. *Rhodamnia cinerea* (Myrtaceae) is

present, and often dominant, at all sites, but the other components are more variable. At one extreme are sites where the light-demanding pioneers, *Adinandra dumosa* (Theaceae) and *Macaranga conifera* (Euphorbiaceae), are still prominent, tree crowns are small and indistinct on aerial photographs, and the canopy height ranges from 8–15 m. At the other extreme, where the canopy has attained 15–25 m, some tree crowns are larger, and most light-demanding species have been eliminated. At this stage, the forest is dominated by tree species in the families Myrtaceae (*Rhodamnia, Syzygium*), Guttiferae (*Calophyllum, Garcinia*), and Lauraceae (*Litsea*), with *Campnospermum auriculatum* (Anacardiaceae), *Elaeocarpus* spp. (Elaeocarpaceae), *Gynotroches axillaris* (Rhizophoraceae), *Ixonanthes reticulata* (Ixonanthaceae) and *Timonius wallichianus* (Rubiaceae). The giant specimens of *Syzygium grandis* (Myrtaceae) in some areas were, apparently, planted as fire-breaks in *Imperata* grassland in the late nineteenth century.

Non-forest vegetation

There has been no detailed study of the non-forest vegetation within the Nature Reserves. Exotic grasses and legumes dominate some recently-abandoned areas on the fringes, while native grasses and the fern, *Dicranopteris*, cover most open areas in the interior. There are also some large patches of native shrubland, dominated by the *Melastoma malabathricum* (Melastomatacaea), *Dillenia suffruticosa* (Dilleniaceae), *Adinandra dumosa* (Theaceae) and *Macaranga heynei* (Euphorbiaceae).

Discussion

Because of the rarity of open habitats in the primeval landscape of Singapore, most of Singapore's surviving non-coastal biodiversity is confined to forest. Man-made, non-forest vegetation is typically species-poor and/or dominated by exotics (Corlett, 1992a, 1992b). Most of the forest vegetation was cleared during the nineteenth and early twentieth centuries, with a minimum probably being reached in the period 1910–1940. Many extinctions occurred during this period of deforestation, with the vertebrates most vulnerable and the vascular plants least (Corlett & Turner, 1997). Subsequently, the forest area has increased as secondary forest developed but extinctions have continued as a result of additional pressures in some areas and, no doubt, as a consequence of the vulnerability of small populations to chance extinction. Secondary forests are now much more extensive than the primary forest remnants they surround (Figure 1) and

some are probably a hundred years or more old. However, secondary forests in Singapore have accumulated species slowly and selectively, and are still floristically impoverished in comparison with the primary forest (Corlett & Turner, 1997; Turner *et al.*, 1997). A major reason for this relative impoverishment seems to be the failure of many primary forest species to disperse out from their refuges, and at least part of this can be attributed to the disproportionate extinction of large seed-dispersing frugivores in Singapore. Preliminary results from the 2-ha permanent plot at Bukit Timah suggest that the same problem may be limiting regeneration of some animal-dispersed species within the primary forest, particularly members of the family Myristicaceae (Ercelawn *et al.*, 1998). The elevated abundance of seed-predating rodents may be another factor limiting colonization of new sites. Whatever the explanation, there is no doubt that preserving all the remaining primary forest remnants from destruction or disturbance must be the basis of any plant conservation strategy in Singapore (Turner & Corlett, 1996).

The importance of the primary forest does not mean, however, that the more extensive secondary forests are of no value. These forests buffer the tiny primary remnants from the harsh external environment and provide the major habitat in Singapore for all those forest-dependent animal species, which do not require the more complex structure and greater floristic diversity of the primary forest. Moreover, both the structural complexity and floristic diversity of the secondary forest will increase with time. The secondary forests are the future of the nature reserves.

Most of the non-forest vegetation of the reserves is of limited conservation value. The native shrubland dominated by *Melastoma, Dillenia, Adinandra* and *Macaranga heynei* may be an exception, since the continuous supply of nectar and small fruits it provides, in contrast to the more "pulsed" supply in the older forest types, may increase the carrying capacity of the reserves as a whole for nectar- and fruit-eating animals. In contrast, the marginal areas dominated by exotic grasses and/or legumes, the bigger patches of *Dicranopteris* fernland, and the grasslands dominated by *Imperata* and other species, support little wildlife. Reforestation of these areas with native species would help reduce fragmentation and increase the total area of habitat available for forest-dependent plant and animal species.

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Checklist of Vascular Plants in the Nature Reserves of Singapore

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Abstract

This vascular plant checklist of the Nature Reserves of Singapore is a compilation of historical records (herbarium specimens, published and unpublished checklists) as well as recent field observations and studies. A total of 1634 species of vascular plants have been recorded in the Nature Reserves since the last century, of which 443 (or 29% of the indigenous species) have not been seen during the last 10 years.

Introduction

The current Nature Reserves of Singapore consist of the Bukit Timah Nature Reserve (BTNR) and the Central Catchment Nature Reserve (CCNR). Floristic inventory and research in the past were mostly concentrated at BTNR, the Bukit Timah Reserve as it was formerly known. It was one of the first Forest Reserves to be established in Singapore in 1883.

In 1951, the Nature Reserves Ordinance was enacted and the Central Catchment Area, now known as the Central Catchment Nature Reserve, was included as one of the five Forest Reserves. In 1990, the newly gazetted National Parks Act established a National Parks Board, which acts as a trustee for the current Nature Reserves.

The objectives of the Nature Reserves are, as stated in Part II of the National Parks Act 1990:

(a) the propagation, protection and preservation of the plants (flora) and animals (fauna) of Singapore;

(b) the study, research and preservation of objects and places of aesthetic, historical or scientific interest;

(c) the study, research and dissemination of knowledge in botany, horticulture, biotechnology and natural and local history;

and the following was added as Part VII in the National Parks Act 1996:

(d) recreational and educational use by the public.

In 1991, a six-year Nature Reserves Survey (NRS) project was initiated by the National Parks Board (NParks), primarily to inventory the physical and biological components of the Nature Reserves, particularly, that of the lesser known CCNR.

Materials

The documentation of Singapore's flora started in the late nineteenth century. A literature and herbarium search at the Singapore Botanic Gardens Herbarium (SING) yielded a long list of historical flora records of the Nature Reserves of Singapore. These include *Report on the Forests of the Straits Settlements* (Cantley, 1884), *Flora of Singapore* (Ridley, 1900), *Freshwater Swamp-forest of South Johore and Singapore* (Corner, 1978); and specimen records by H.N. Ridley, I.H. Burkill, R.E. Holttum, E.J.H. Corner, and more recently, J. Sinclair in the 1950s–1960s.

After a lapse of about 30 years, interest in biodiversity revived when field collections were carried out at Lower Peirce (within the CCNR) under an independently commissioned survey for a separate project proposal in 1990. This was followed by the NRS project, of which floristic inventory was the primary component during the period 1991 to 1994. Field surveys of the CCNR flora were conducted by NParks staff and consultants (Wong *et al.,* 1994; Ali *et al.,* 1997), and researchers and student assistants from the National University of Singapore (Turner *et al.,* 1994, 1996a, 1996b, 1996c, 1997).

Besides these recent compilations of Singapore flora, checklists (Turner *et al.*, 1990, Turner,1993, 1995; Wee & Ng, 1994; Ng & Wee, 1994; Chin *et al.*, 1995; Tan, 1995) and selected flora inventory research carried out in the Nature Reserves in the last decade (Wong, 1987; Swan, 1988; Corlett, 1990, 1991; Sim *et al.*, 1992; Tan *et al.*, 1995; LaFrankie *et al.*, 1996; Chua *et al.*, 1996) are available.

In addition, the flora in a two-hectare plot in the BTNR is under a long-term population dynamic study carried out by the National Institute of Education, Nanyang Technological University, in conjunction with the Center for Tropical Forest Science (CTFS).

Methods

The compiled list of indigenous vascular plant species (Appendix 1) that are or were probably found growing in the Nature Reserves since the last century is derived from the various publications listed above, herbarium records in the Singapore Botanic Gardens Herbarium, and the unpublished checklists noted below. Naturalised species sampled in the survey are recorded in Appendix 2. The record sources for the four columns, **R**, **H**, **P** and **S**, in Appendices 1 and 2 are as follows:

R — records from field collections, published data from NRS, and published data during the period 1991 – 1997 from the "Additions to the Flora of Singapore" and "The Angiosperm Flora of Singapore" series published in the Gardens' Bulletin Singapore, 44 – 49.

H — herbarium specimens records in SING.

P — publication records denoted as follows: C – Corlett (1990, 1991); F – Wee (1983, 1984); N – Corner (1978); T – Chua *et al.* (1996), Tan *et al.* (1995), Tan (1995, 1997); W – Wong (1987).

S — unverified records denoted as follows: 1 – observations from NParks staff and NRS unpublished checklists, 2 – unpublished checklist of BTNR flora (Corlett, late 80s), 3 – collections from the Centre for Natural Product Research (CNPR) project and 4 – collections from the CTFS project.

The records reported under **S** are non-exhaustive. Sources 1, 3 and 4 are complementary to **R** while source 2 is complementary to **H**, based on dates of collections. Of the new unverified records discovered from this survey that are not found in the Singapore checklist (Turner, 1993), those that have not been recorded as far south as Johore, the nearest state of Peninsula Malaysia, were left out.

Observations

The total vascular plant records for the Nature Reserves of Singapore is 1634 species, as listed in Appendices 1 and 2. Of these species, 1525 are indigenous (Appendix 1) and 109 (7%) are exotic (Appendix 2). For the NRS, 916 species (under **R**) were recorded with an additional 258 species (1, 3 & 4 under **S**) noted during the period.

A total of 1190 vascular plant species are recorded for the Nature Reserves within the last 10 years, of which 341 species or 29% (excluding those listed in recent publications under **P**) are new records for the Nature Reserves.

Of the 1267 old records (those older than 10 years) for the Nature Reserves, 443 (35%) species were not seen during this NRS project period. Some of these species may be extinct as a result of habitat loss (tidal freshwater swamp where the present Upper Seletar Reservoir resides) and forest fragmentation due to clearing and cultivation within the century. Others probably still survive in the Nature Reserves.

Out of 1190 species recorded within the last ten years in the Nature Reserves, 90 (7.5%) are exotic. In comparison, only 11 (0.8%) species out of 1297 species were exotic for records earlier than the last ten years, an eight fold increase in ten years.

Discussion

From the literature survey, it can be seen that in the last few decades there was an absence of field work in the CCNR. It is noteworthy that prior to the NRS, the Singapore flora checklist comprises mainly records more than 30 years old. Consequently, the NRS inventory sets an important milestone in the documentation of flora in Singapore in filling this gap.

Records of lianas, herbaceous, climbing and creeping epiphytes, terrestrial ferns, sedges, grasses, and aquatic and semi-aquatic flora are also expected to be not as complete as that of the tree flora in the NRS, as these were randomly sampled rather than sampled intentionally as defined taxonomic groups.

As noted above, exotics have been invading the Nature Reserves within the last few decades. The number of exotic species establishing in the Nature Reserves should be monitored in future surveys for management implications in the conservation of indigenous species.

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Appendix 1. Indigenous vascular plant species in the Nature Reserves.

(**R** – records from field collections, published data from NRS, and published data during the period 1991–1997 from the "Additions to the Flora of Singapore" and "The Angiosperm Flora of Singapore" series published in the *Gardens' Bulletin Singapore* **44–49**.
H – herbarium specimens records in SING.
P – publication records denoted as follows: C–Corlett (1990, 1991); F–Wee (1983, 1984); N–Corner (1978); T–Chua *et al.* (1996), Tan *et al.* (1995), Tan (1995, 1997); W–Wong (1987).
S – unverified records denoted as follows: 1–observations from NParks staff and NRS unpublished checklists, 2–unpublished checklist of BTNR flora (Corlett, late 80s), 2–collections from the Centre for Natural Product Research (CNPR) project and 4–collections from the CTFS project.)

Species	R	H	P	S
ACANTHACEAE				
Hygrophila ringens (L.) R. Br. *ex* Steud.	+			2
Justicia vasculosa Wall.	+			
Peristrophe roxburghiana (Schult.) Bremek.				1
Ruellia repens L.	+			
Staurogyne griffithiana (Nees) Kuntze				2
Staurogyne setigera (Nees) Kuntze	+			2
ACTINIDIACEAE				
Saurauia pentapetala (Jack) Hoogland		+		
ADIANTACEAE				
Adiantum flabellulatum L.			F	
Syngramma alismifolia (C. Presl) J.J. Sm.	+			
Taenitis blechnoides (Willd.) Sw.	+		F	
Taenitis interrupta Hook. & Grev.	+			
ALANGIACEAE				
Alangium ebenaceum (C.B. Clarke) Harms			N	
Alangium griffithii (C.B. Clarke) Harms		+		
Alangium nobile (C.B. Clarke) Harms	+	+	C	
Alangium ridleyi King		+	C	

Species	R	H	P	S
AMARANTHACEAE				
Alternanthera sessilis (L.) DC.	+			
Amaranthus tricolor L.	+			
Cyathula prostrata (L.) Blume				1
ANACARDIACEAE				
Bouea macrophylla Griff.			W	
Bouea oppositifolia (Roxb.) Meisn.	+	+	W	
Buchanania arborescens (Blume) Blume	+	+		
Buchanania sessifolia Blume	+	+	CW	
Campnosperma auriculatum (Blume) Hook.*f.*	+	+	CNW	
Campnosperma squamatum Ridl.	+	+	N	
Dracontomelon dao (Blanco) Merr. & Rolfe				1
Gluta wallichii (Hook.*f.*) Ding Hou	+	+	CNW	
Mangifera caesia Jack				1
Mangifera foetida Lour.	+			
Mangifera griffithii Hook.*f.*	+	+		
Mangifera lagenifera Griff.				2
Mangifera macrocarpa Blume		+		
Mangifera odorata Griff.		+		
Mangifera quadrifida Jack		+	N	
Mangifera subsessilifolia Kosterm.	+	+		
Melanochyla auriculata Hook.*f.*	+	+	N	
Melanochyla bracteata King		+		
Melanochyla caesia (Bl.) Ding Hou	+	+	N	
Melanochyla fulvinervis (Blume) Ding Hou		+		
Parishia insignis Hook.*f.*		+		1
Parishia maingayi Hook.*f.*	+	+		
Parishia paucijuga Engl.		+	W	1
Swintonia schwenkii (Teijsm. & Binn.) Teijsm. & Binn.	+	+		
ANCISTROCLADACEAE				
Ancistrocladus tectorius (Lour.) Merr.	+			
ANISOPHYLLEACEAE				
Anisophyllea disticha (Jack) Baill.	+	+	N	

Species	R	H	P	S
Anisophyllea griffithii Oliv.			C	1
ANNONACEAE				
Alphonsea maingayi Hook.*f.* & Thomson	+			
Anaxagorea javanica Blume			W	
Artabotrys costatus King	+			
Artabotrys crassifolius Hook.*f.* & Thomson		+		
Artabotrys maingayi Hook.*f.* & Thomson		+		1
Artabotrys suaveolens (Blume) Blume	+	+	C	
Artabotrys wrayi King		+		
Cyathocalyx ramuliflorus (Maingay *ex* Hook.*f.* & Thomson) Scheff.	+		CW	
Cyathocalyx ridleyi (King) J. Sinclair	+		CW	
Cyathostemma viridiflorum Griff.	+	+	N	
Desmos chinensis Lour.				1
Desmos dasymaschalus (Blume) Safford	+	+		
Desmos dumosus (Roxb.) Safford		+		
Ellipeia cuneifolia Hook.*f.* & Thomson	+			
Fissistigma fulgens (Hook.*f.* & Thomson) Merr.	+	+		
Fissistigma lanuginosum (Hook.*f.* & Thomson) Merr.		+	W	
Fissistigma latifolium (Dunal) Merr.		+	W	
Friesodielsia biglandulosa (Blume) Steenis		+	N	
Friesodielsia borneensis (Miq.) Steenis		+	N	
Friesodielsia latifolia (Hook.*f.* & Thomson) Steenis	+	+		
Goniothalamus macrophyllus (Blume) Hook.*f.* & Thomson	+			2
Goniothalamus malayanus Hook.*f.* & Thomson		+		
Goniothalamus ridleyi King	+		N	
Goniothalamus tapis Miq.				2,4
Meiogyne virgata (Blume) Miq.		+		3
Mezzettia parviflora Becc.	+	+	CN	
Miliusa longipes King		+		
Mitrella kentii (Blume) Miq.	+	+	N	
Monocarpia marginalis (Scheff.) J. Sinclair	+			
Phaeanthus ophthalmicus (Roxb. *ex* G. Don) J. Sinclair	+		C	
Polyalthia angustissima Ridl.	+		N	
Polyalthia cauliflora Hook.*f.* & Thomson	+	+		
Polyalthia clavigera King		+		

Species	R	H	P	S
Polyalthia glauca (Hassk.) F. Muell.	+		N	
Polyalthia hookeriana King	+		W	
Polyalthia hypoleuca Hook.*f.* & Thomson				4
Polyalthia jenkensii (Hook.*f.* & Thomson) Hook.*f.* & Thomson	+	+		
Polyalthia lateriflora (Blume) King	+		N	
Polyalthia macropoda King	+			2
Polyalthia rumphii (Blume) Merr.	+		W	
Polyalthia sclerophylla Hook.*f.* & Thomson			N	
Polyalthia sumatrana (Miq.) Kurz	+		C	
Popowia fusca King	+	+	C	
Popowia pisocarpa (Blume) Endl.	+	+	C	
Popowia tomentosa Maingay *ex* Hook.*f.* & Thomson			N	4
Pyramidanthe prismatica (Hook.*f.* & Thomson) J. Sinclair	+	+	C	
Uvaria cordata (Dunal) Alston	+	+		
Uvaria curtisii King		+		
Uvaria grandiflora Roxb. *ex* Hornem.		+		1
Uvaria hirsuta Jack	+			
Uvaria leptpoda (King) R.E. Fr.		+		
Uvaria pauci-ovulata Hook.*f.* & Thomson		+		
Xylopia caudata Hook.*f.* & Thomson	+	+	N	
Xylopia ferruginea (Hook.*f.* & Thomson) Hook.*f.* & Thomson	+	+	CW	
Xylopia fusca Maingay *ex* Hook.*f.* & Thomson	+		N	
Xylopia magna Maingay *ex* Hook.*f.* & Thomson	+			
Xylopia malayana Hook.*f.* & Thomson	+		CNW	
APOCYNACEAE				
Alstonia angustifolia Wall. *ex* A. DC.	+	+	CNW	
Alstonia angustiloba Miq.	+	+	C	
Alstonia macrophylla Wall. *ex* G. Don	+			
Alstonia pneumatophora Back. *ex* L.G. den Berger	+			
Alstonia spatulata Blume		+	N	1
Alyxia reinwardtii Blume				1
Chonemorpha fragrans (Moon) Alston	+			
Dyera costulata (Miq.) Hook.*f.*	+	+	W	
Ichnocarpus serpyllifolius (Blume) P.I. Forst.	+			
Kibatalia maingayi (Hook.*f.*) R.E. Woodson	+			

Species	R	H	P	S
Kopsia singapurensis Ridl.	+		NT	
Leuconotis griffithii Hook.*f.*	+	+		
Leuconotis maingayi Dyer *ex* Hook.*f.*	+	+		
Parameria laevigata (A.L. Juss.) Moldenke				1
Parameria polyneura Hook.*f.*		+	N	
Parsonsia curvisepala K. Schum.		+		
Strophanthus caudatus (L.) Kurz		+		
Tabernaemontana corymbosa Roxb. *ex* Wall.	+	+	N	
Tabernaemontana pauciflora Blume	+	+		
Tabernaemontana peduncularis Wall.				2
Urceola brachysepala Hook.*f.*		+		
Urceola elastica Roxb.	+			
Urceola torulosa Hook.*f.*		+	N	
Willughbeia angustifolia (Miq.) Markgr.		+		
Willughbeia edulis Roxb.	+	+	CN	
Willughbeia flavescens Dyer *ex* Hook.*f.*		+	N	
Willughbeia tenuiflora Dyer *ex* Hook.*f.*	+	+		
Wrightia laevis Hook.*f.*		+		
AQUIFOLIACEAE				
Ilex cymosa Blume	+	+	N	
Ilex macrophylla Hook.*f.*	+	+	N	
Ilex maingayi Hook.*f.*		+		
ARACEAE				
Aglaonema nebulosum N.E. Br.	+	+		
Aglaonema nitidum (Jack) Kunth	+	+	N	
Aglaonema simplex Blume	+			2
Alocasia denudata Engl.	+	+	N	
Amorphophallus paeoniifolius (Dennst.) Nicolson				2
Amorphophallus prainii Hook.*f.*				2
Amydrium medium (Zoll. & Moritzi) Nicolson				1,2
Anadendrum montanum (Blume) Schott	+		N	
Colocasia esculenta (L.) Schott	+			
Cryptocoryne griffithii Schott	+			2
Cyrtosperma merkusii (Hassk.) Schott	+			

Species	R	H	P	S
Epipremnum giganteum (Roxb.) Schott				1,2
Epipremnum pinnatum (L.) Engl.				1,2
Homalomena confusa Furtado				1
Homalomena griffithii (Schott) Hook.*f.*	+	+		
Homalomena humilis (Jack) Hook.*f.*		+		1
Homalomena paludosa Hook.*f.*				2
Homalomena pygmaea (Hassk.) Engl.		+		
Homalomena sagittifolia Jungh. *ex* Schott	+		N	
Lasia spinosa (L.) Thw.				1
Pistia stratiotes L.				1
Pothos peninsularis Alderw.	+		N	
Rhaphidophora korthalsii Schott	+			2
Rhaphidophora lobbii Schott	+			2
Rhaphidophora sylvestris (Blume) Engl.	+			2
Schismatoglottis calyptrata (Roxb.) Zoll. & Moritzi				1,2
Schismatoglottis wallichii (Roxb.) Hook.*f.*	+			2
Scindapsus hederaceus Miq.	+			2
Scindapsus pictus Hassk.	+			2
Typhonium roxburghii Schott		+		
ARALIACEAE				
Arthrophyllum diversifolium Blume	+	+	N	
Schefflera elliptica (Blume) Harms		+		
ARALIDIACEAE				
Aralidium pinnatifitidum (Jungh. & de Vriese) Miq.		+		
ARISTOLOCHIACEAE				
Thottea grandiflora Rottb.	+	+		
ASCLEPIADACEAE				
Cynanchum ovalifolium Wight		+		
Dischidia albiflora Griff.				2
Dischidia cochleata Blume		+		
Dischidia hirsuta (Blume) Decne.			N	
Dischidia major (Vahl) Merr.	+			2

Species	R	H	P	S
Dischidia nummularia R. Br.	+		N	
Genianthus maingayi Hook.*f.*		+		
Hoya lacunosa Blume	+	+		
Hoya latifolia G. Don		+		1
Hoya obtusifolia Wight				2
Hoya verticillata (Vahl) G. Don	+			
Toxocarpus griffithii Decne.		+		
ASPLENIACEAE				
Asplenium batuense Alderw.	+			
Asplenium longissimum Blume	+		F	
Asplenium macrophyllum Sw.		+		
Asplenium nidus L.	+		FN	
Asplenium tenerum G. Forst.	+		F	
BALSAMINACEAE				
Hydrocera triflora (L.) Wight & Arn.	+			
BIGNONIACEAE				
Deplanchea bancana (Scheff.) Steenis			N	
Radermachera pinnata (Blanco) Seem.		+		4
Stereospermum colais (Dillwyn) Mabb.		+		
BLECHNACEAE				
Blechnum finlaysonianum Wall. *ex* Hook. & Grev.	+	+	F	
Blechnum orientale L.	+		FN	
Stenochlaena palustris (Burm. *f.*) Bedd.	+		N	
BOMBACACEAE				
Coelostegia griffithii Benth.		+	N	4
Durio griffithii (Mast.) Bakh.	+	+	CW	
Durio singaporensis Ridl.	+	+	N	
Neesia altissima (Blume) Blume			C	
Neesia malayana Bakh.		+	N	1
Neesia synandra Mast.	+	+	T	

Species	R	H	P	S
BORAGINACEAE				
Heliotropium indicum L.	+			
BURMANNIACEAE				
Burmannia championii Thw.		+		
Burmannia coelestis D. Don	+		T	
Gymnosiphon aphyllus Blume				2
Thismia aseroe Becc.			T	2
Thismia fumida Ridl.				2
BURSERACEAE				
Canarium grandifolium (Ridl.) H.J. Lam	+		W	2
Canarium littorale Blume	+	+	C	
Canarium odontophyllum Miq.		+	N	
Canarium patentinervium Miq.	+	+		
Canarium pilosum Benn.	+	+	N	
Dacryodes costata (Benn.) H.J. Lam	+	+	W	
Dacryodes incurvata (Engl.) H.J. Lam		+	N	
Dacryodes laxa (Benn.) H.J. Lam	+	+	W	
Dacryodes longifolia (King) H.J. Lam				4
Dacryodes rostrata (Blume) H.J. Lam	+	+	NW	
Dacryodes rugosa (Blume) H.J. Lam		+	W	
Santiria apiculata Benn.	+	+	CNW	
Santiria conferta Benn.		+		
Santiria griffithii (Hook.*f.*) Engl.	+	+	NW	
Santiria laevigata Blume	+	+	W	
Santiria oblongifolia Blume		+		
Santiria rubiginosa Blume	+	+	NW	
Santiria tomentosa Blume	+	+	W	
Triomma malaccensis Hook.*f.*	+			2
CAMPANULACEAE				
Lobelia zeylanica L.		+		3
CAPPARACEAE				
Capparis micracantha DC.		+		

Species	R	H	P	S
CAPRIFOLIACEAE				
Viburnum sambucinum Blume		+		
CECROPIACEAE				
Poikilospermum suaveolens (Blume) Merr.	+	+	C	
CELASTRACEAE				
Bhesa paniculata Arn.	+	+	CNW	
Bhesa robusta (Roxb.) Ding Hou	+			
Cassine viburnifolia (Juss.) Ding Hou		+		
Euonymus javanicus Blume			N	
Kokoona reflexa (Lawson) Ding Hou	+		CW	
Lophopetalum multinervium Ridl.	+	+	N	
Lophopetalum pachyphyllum King		+		
Lophopetalum wightianum Arn.	+	+	C	
Salacia grandiflora Kurz	+	+		
Salacia korthalsiana Miq.		+		
Salacia macrophylla Blume		+		
Salacia viminea Wall. *ex* Lawson		+		
CHLORANTHACEAE				
Chloranthus erectus (Buch.-Ham.) Verdc.		+		
CHRYSOBALANACEAE				
Atuna racemosa Raf.		+		
Licania splendens (Korth.) Prance	+	+	CW	
Maranthes corymbosa Blume	+	+	C	
Parastemon urophyllus (Wall. *ex* A. DC.) A. DC.		+	N	3
Parinari costata (Korth.) Blume		+	N	
Parinari oblongifolia Hook.*f.*	+	+	N	
COMBRETACEAE				
Combretum sundaicum Miq.		+	C	
Terminalia phellocarpa King		+	N	
Terminalia subspathulata King	+	+		

Species	R	H	P	S
COMMELINACEAE				
Amischotolype gracilis (Ridl.) I.M. Turner	+			2
Amischotolype marginata Hassk.		+		
Commelina benghalensis L.				1
Commelina diffusa Burm.*f.*	+			
Murdannia nudiflora (L.) Brenan				1
COMPOSITAE				
Acmella uliginosa (Sw.) Cass.		+		
Blumea balsamifera (L.) DC.				1
Blumea lacera (Burm.*f.*) DC.	+			
Eclipta prostrata (L.) L.	+			
Elephantopus scaber L.	+			
Emilia sonchifolia (L.) DC.	+	+		
Gynura procumbens (Lour.) Merr.		+		
Vernonia arborea Buch.-Ham.		+	T	3
Vernonia cinerea (L.) Less.				1
CONNARACEAE				
Agelaea borneensis (Hook.*f.*) Merr.	+	+	W	
Agelaea macrophylla (Zoll.) Leenh.	+	+		
Cnestis palala (Lour.) Merr.	+		N	
Connarus ferrugineus Jack		+		
Connarus grandis Jack		+		3
Connarus monocarpus L.		+	N	
Connarus planchonianus Schellenb.		+		
Connarus semidecandrus Jack		+	N	
Ellipanthus tomentosus Kurz		+	W	4
Rourea fulgens Planch.	+			
Rourea mimosoides (Vahl) Planch.	+	+		
Rourea minor (Gaertn.) Leenh.		+	CN	1
CONVALLARIACEAE				
Peliosanthes teta Andrews	+	+		
CONVOLVULACEAE				

Species	R	H	P	S
Argyreia ridleyi (Prain) Prain *ex* Ooststr.	+		N	
Erycibe griffithii C.B. Clarke			N	
Erycibe leucoxyloides King *ex* Prain				2
Erycibe maingayi C.B. Clarke				2
Erycibe malaccensis C.B. Clarke	+			2
Erycibe tomentosa Blume	+			
Ipomoea pes-caprae (L.) R. Br.	+			
Merremia hederacea (Burm.*f.*) Hallier *f.*	+			
Merremia umbellata (L.) Hallier *f.*				3
Neuropeltis racemosa Wall.				1,2
Xenostegia tridentata (L.) D.F. Austin & Staples	+			
CORNACEAE				
Mastixia pentandra Blume				4
Mastixia trichotoma Blume	+	+		
COSTACEAE				
Costus globosus Blume		+		
Costus speciosus (J. König) Sm.	+	+		
CRYPTERONIACEAE				
Crypteronia griffithii C.B. Clarke		+	T	
CTENOLOPHONACEAE				
Ctenolophon parvifolius Oliv.	+			
CUCURBITACEAE				
Trichosanthes celebica Cogn.	+	+		
Trichosanthes wallichiana (Ser.) Wight		+		
Trichosanthes wawraei Cogn.	+	+		
CYATHEACEAE				
Cyathea glabra (Blume) Copel.	+		FN	
Cyathea latebrosa (Wall. *ex* Hook.) Copel.	+		FN	
Cyathea squamulata (Blume) Copel.			F	

Species	R	H	P	S
CYPERACEAE				
Actinoscirpus grossus (L.*f.*) Goetghebeur & D.A. Simpson		+		
Carex cryptostachys Brongn.		+		
Cyperus digitatus Roxb.	+			
Cyperus distans L.*f.*		+		
Cyperus haspan L.	+	+		
Cyperus laxus Lam.		+		
Diplacrum caricinum R. Br.		+		
Eleocharis dulcis (Burm.*f.*) Hensch.		+		
Eleocharis ochrostachys Steud.		+		
Fimbristylis acuminata Vahl		+		
Fimbristylis dichotoma (L.) Vahl		+		
Fimbristylis dura (Zoll. & Moritzi) Merr.		+		
Fimbristylis obtusata (C.B. Clarke) Ridl.		+		
Fimbristylis pauciflora R. Br.		+		
Fimbristylis umbellaris (Lam.) Vahl	+			
Fuirena umbellata Rottb.		+		
Gahnia tristis Nees	+	+		
Hypolytrum nemorum (Vahl) Spreng.	+	+		
Kyllinga brevifolius Rottb.		+		
Lipocarpha microcephala (R. Br.) Kunth		+		
Mapania bancana (Miq.) Benth. & Hook. *ex* B.D. Jacks.	+		N	
Mapania cuspidata (Miq.) Uittien	+	+		
Mapania enodis (Miq.) C.B. Clarke			N	
Mapania kurzii C.B. Clarke		+		
Mapania palustris (Hassk. *ex* Steud.) Fern.-Vill.	+	+		
Mapania squamata (Kurz) C.B. Clarke	+	+		
Mapania wallichii C.B. Clarke		+		
Rhynchospora corymbosa (L.) Britt.	+	+		
Rhynchospora rubra (Lour.) Makino		+		
Schoenoplectus mucronatus (L.) Palla		+		
Scleria biflora Roxb.	+	+		
Scleria ciliaris Nees	+			
Scleria corymbosa Roxb.		+		
Scleria levis Retz.	+	+		
Scleria purpurascens Steud.		+		

Species	R	H	P	S
Scleria rugosa R. Br.		+		
Scleria sumatrensis Retz.		+		
Scleria terrestris (L.) Fassett		+		
DAPHNIPHYLLACEAE				
Daphniphyllum laurinum (Benth.) Baill.	+			
DAVALLIACEAE				
Davallia angustata Wall. *ex* Hook. & Grev.		+		
Davallia solida (G. Forst.) Sw.			F	
Davallia triphylla Hook.			F	
DENNSTAEDTIACEAE				
Histiopteris incisa (Thunb.) J.J. Sm.	+		N	
Lindsaea cultrata (Willd.) Sw.			F	
Lindsaea divergens Hook. & Grev.			F	
Lindsaea doryophora K.U. Kramer	+		F	
Lindsaea ensifolia Sw.	+		F	
Lindsaea parasitica (Roxb. *ex* Griff.) Hieron.	+		N	
Microlepia speluncae (L.) T. Moore	+			
Pteridium esculentum (G. Forst.) Cockayne	+		F	
DILLENIACEAE				
Dillenia excelsa (Jack) Gilg		+		4
Dillenia grandifolia Wall. *ex* Hook.*f.* & Thomson	+	+	NW	
Dillenia pulchella (Jack) Gilg		+		
Dillenia reticulata King				2,4
Dillenia suffruticosa (Griff.) Mart.	+	+		
Tetracera akara (Burm.*f.*) Merr.		+	N	
Tetracera arborescens Jack			N	1
Tetracera fagifolia Blume		+		3
Tetracera indica (Christm. & Panz.) Merr.	+	+		
Tetracera macrophylla Wall. *ex* Hook.*f.* & Thomson				1
DIOSCOREACEAE				
Dioscorea laurifolia Wall. *ex* Hook.*f.*	+	+		

Species	R	H	P	S
Dioscorea polyclades Hook.*f.*		+		
Dioscorea prainiana Knuth	+	+		
Dioscorea pyrifolia Kunth	+	+		
Dioscorea stenomeriflora Prain & Burkill	+			
DIPTEROCARPACEAE				
Anisoptera laevis Ridl.	+			
Anisoptera megistocarpa Slooten	+	+	NW	
Dipterocarpus caudatus Foxw.		+	CW	4
Dipterocarpus cornutus Dyer	+	+		
Dipterocarpus elongatus Korth.	+	+		
Dipterocarpus grandiflorus (Blanco) Blanco	+			
Dipterocarpus kunstleri King		+		1
Dipterocarpus palembanicus Slooten				1
Dipterocarpus sublamellatus Foxw.	+	+	W	
Hopea griffithii Kurz	+	+		
Hopea mengarawan Miq.	+	+	CW	
Hopea sangal Korth.		+		
Shorea bracteolata Dyer	+		W	
Shorea collina Ridl.		+		
Shorea curtisii Dyer *ex* King	+	+	CW	
Shorea gibbosa Brandis	+			
Shorea gratissima (Wall. *ex* Kurz) Dyer	+	+	NW	
Shorea leprosula Miq.	+	+	W	
Shorea macroptera Dyer	+	+	NW	
Shorea ochrophloia Strugnell *ex* Symington	+			4
Shorea ovalis (Korth.) Blume	+	+		
Shorea parvifolia Dyer	+	+	C	
Shorea pauciflora King	+	+	W	
Shorea platycarpa F. Heim	+	+	N	
Vatica maingayi Dyer	+	+	CW	
Vatica nitens King		+		
Vatica pauciflora (Korth.) Blume		+	N	
Vatica ridleyana Brandis	+	+		
Vatica stapfiana (King) Slooten		+		

Species	R	H	P	S
DRACAENACEAE				
Dracaena cantleyi Baker	+	+		
Dracaena elliptica Thunb.			N	1
Dracaena granulata Hook.*f.*	+	+		
Dracaena maingayi Hook.*f.*		+	T	1
Dracaena porteri Baker	+	+		
Dracaena singapurensis Ridl.		+		1
Dracaena umbratica Ridl.	+	+		
DRYOPTERIDACEAE				
Heterogonium sagenioides (Mett.) Holttum			F	
Pleocnemia olivacea (Copel.) Holttum	+			
Tectaria barberi (Hook.) Copel.		+		
Tectaria singaporeana (Hook. & Grev.) Copel.	+	+	F	
EBENACEAE				
Diospyros argentea Griff.		+		
Diospyros buxifolia (Blume) Hiern	+	+	W	
Diospyros clavigera C.B. Clarke		+		4
Diospyros confusa Bakh.		+		4
Diospyros coriacea Hiern		+	N	4
Diospyros diepenhorstii Miq.		+		4
Diospyros lanceifolia Roxb.	+	+	CNW	
Diospyros maingayi (Hiern) Bakh.	+	+	NW	
Diospyros pilosanthera Blanco	+	+	N	
Diospyros ridleyi Bakh.	+			
Diospyros siamang Bakh.			N	
Diospyros styraciformis King & Gamble	+	+	C	
Diospyros sumatrana Miq.		+		
ELAEOCARPACEAE				
Elaeocarpus acmosepalus Ridl.		+		
Elaeocarpus ferrugineus (Jack) Steud.	+	+	C	
Elaeocarpus floribundus Blume	+	+		
Elaeocarpus griffithii (Wight) A. Gray		+	N	
Elaeocarpus mastersii King	+	+	CNW	

Species	R	H	P	S
Elaeocarpus nitidus Jack	+	+	CW	
Elaeocarpus palembanicus (Miq.) Corner	+	+		
Elaeocarpus petiolatus (Jack) Wall.	+	+	CW	
Elaeocarpus polystachyus Wall. *ex* C. Müll. Berol.	+	+	NW	
Elaeocarpus rugosus Roxb.	+	+		
Elaeocarpus stipularis Blume	+	+		
ERICACEAE				
Rhododendron longiflorum Lindl.		+		
ERIOCAULACEAE				
Eriocaulon truncatum Buch.-Ham. *ex* Mart.		+		
Eriocaulon willdenovianum Moldenke	+	+		
ESCALLONIACEAE				
Polyosma kingiana Schltr.		+		1
EUPHORBIACEAE				
Actephila excelsa (Dalzell) Müll. Arg.	+	+	C	
Agrostistachys longifolia (Wight) Benth.	+	+	CN	
Alchornea villosa (Benth.) Müll. Arg.	+	+	N	
Antidesma coriaceum Tul.	+	+	CW	
Antidesma cuspidatum Müll. Arg.	+	+	CW	
Antidesma neurocarpum Miq.	+	+		
Aporusa benthamiana Hook.*f.*	+	+	CW	
Aporusa bracteosa Pax & K. Hoffm.	+	+	W	
Aporusa confusa Gage	+			2
Aporusa falcifera Hook.*f.*		+		4
Aporusa frutescens Blume	+	+		
Aporusa lunata (Miq.) Kurz				4
Aporusa microstachya (Tul.) Müll. Arg.	+			2
Aporusa miqueliana Müll. Arg.	+			
Aporusa nervosa Hook.*f.*	+	+		
Aporusa nigricans Hook.*f.*		+		4
Aporusa penangensis (Ridl.) Airy Shaw	+			
Aporusa prainiana King *ex* Gage	+		W	

Species	R	H	P	S
Aporusa symplocoides (Hook.*f.*) Gage	+		C	
Austrobuxus nitidus Miq.			N	
Baccaurea bracteata Müll. Arg.		+	W	3
Baccaurea brevipes Hook.*f.*	+			
Baccaurea griffithii Hook.*f.*		+		4
Baccaurea hookeri Gage	+			
Baccaurea kunstleri King *ex* Gage	+	+	CNW	
Baccaurea lanceolata (Miq.) Müll. Arg.				2
Baccaurea macrophylla (Müll. Arg.) Müll. Arg.		+		
Baccaurea maingayi Hook.*f.*	+	+	W	
Baccaurea minor Hook.*f.*	+	+		
Baccaurea motleyana (Müll. Arg.) Müll. Arg.		+		1
Baccaurea parviflora (Müll. Arg.) Müll. Arg.	+	+	C	
Baccaurea racemosa (Reinw.) Müll. Arg.	+	+		
Baccaurea reticulata Hook.*f.*	+	+		
Baccaurea sumatrana Müll. Arg.	+	+	W	
Blumeodendron tokbrai (Blume) J.J. Sm.	+	+	NW	
Breynia coronata Hook.*f.*	+			
Breynia discigera Müll. Arg.		+		
Breynia reclinata (Roxb.) Hook.*f.*	+			2
Bridelia cinnamomea Hook.*f.*		+		
Bridelia griffithii Hook.*f.*		+	N	
Bridelia pustulata Blume		+		3
Bridelia stipularis (L.) Blume		+		1
Bridelia tomentosa Blume		+		3
Cheilosa montana Blume	+			
Claoxylon indicum (Reinw. *ex* Blume) Endl. *ex* Hassk.	+	+		
Claoxylon longifolium (Blume) Endl. *ex* Hassk.		+		
Cleistanthus hirsutulus Hook.*f.*		+		
Cleistanthus macrophyllus Hook.*f.*		+		
Cleistanthus sumatranus (Miq.) Müll. Arg.	+	+		
Croton caudatus Geisel.		+		3
Croton laevifolius Blume	+	+	N	
Drypetes laevis (Miq.) Pax & K. Hoffm.				4
Drypetes longifolia (Blume) Pax & K. Hoffm.				4
Drypetes pendula Ridl.	+	+	N	

Species	R	H	P	S
Elateriospermum tapos Blume			W	
Endospermum diadenum (Miq.) Airy Shaw	+	+	CNW	
Glochidion arborescens Blume		+		
Glochidion borneense (Müll. Arg.) Boerl.		+		
Glochidion brunneum Hook.*f.*		+		
Glochidion hypoleucum (Miq.) Boerl.		+	N	3
Glochidion littorale Blume	+			
Glochidion rubrum Blume		+	N	
Glochidion sericeum Hook.*f.*		+	N	
Glochidion singaporense Gage		+		
Glochidion superbum Baill.	+	+		
Koilodepas longifolium Hook.*f.*	+	+	W	
Macaranga conifera (Zoll.) Müll. Arg.	+	+	CNW	
Macaranga gigantea (Rchb.*f.* & Zoll.) Müll. Arg.	+	+	CN	
Macaranga heynei I.M. Johnst.	+	+		
Macaranga hullettii King *ex* Hook.*f.*		+		
Macaranga hypoleuca (Rchb.*f.* & Zoll.) Müll. Arg.	+	+	N	
Macaranga lowii King *ex* Hook.*f.*	+	+	W	
Macaranga motleyana (Müll. Arg.) Müll. Arg.		+	N	
Macaranga puncticulata Gage	+		N	
Macaranga recurvata Gage		+	N	
Macaranga trichocarpa (Rchb.*f.* & Zoll.) Müll. Arg.		+	CN	
Macaranga triloba (Blume) Müll. Arg.	+	+	CN	
Mallotus macrostachyus (Miq.) Müll. Arg.		+		
Mallotus paniculatus (Lam.) Müll. Arg.	+	+		
Mallotus penangensis Müll. Arg.	+		W	
Neoscortechinia kingii (Hook.*f.*) Pax & K. Hoffm.	+			
Paracroton pendulus (Hassk.) Miq.	+	+		
Phyllanthus emblica L.		+		
Phyllanthus urinaria L.				1
Pimelodendron griffithianum (Müll. Arg.) Benth.	+	+	CNW	
Ptychopyxis caput-medusae (Hook.*f.*) Ridl.		+	W	1
Ptychopyxis costata Miq.				1
Sapium discolor (Champ. *ex* Benth.) Müll. Arg.		+	N	1
Sauropus androgynus (L.) Merr.	+			
Trigonopleura malayana Hook.*f.*				4

Species	R	H	P	S
Trigonostemon longifolius Baill.	+			2
Trigonostemon malaccanus Müll. Arg.				4
Trigonostemon villosus Hook.*f.*	+			
FAGACEAE				
Castanopsis inermis (Lindl. *ex* Wall.) Benth. & Hook.*f.*		+	N	
Castanopsis lucida (Nees) Soepadmo	+	+		
Castanopsis malaccensis Gamble		+		
Castanopsis megacarpa Gamble	+	+	W	
Castanopsis nephelioides King *ex* Hook.*f.*	+	+		
Castanopsis schefferana Hance	+			
Castanopsis wallichii King *ex* Hook.*f.*	+	+	CW	
Lithocarpus bennettii (Miq.) Rehder	+	+	N	
Lithocarpus cantleyanus (King *ex* Hook.*f.*) Rehder	+	+		
Lithocarpus conocarpus (Oudem.) Rehder	+	+	W	
Lithocarpus elegans (Blume) Hatus. *ex* Soepadmo		+	N	4
Lithocarpus encleisacarpus (Korth.) A. Camus	+	+	CW	
Lithocarpus ewyckii (Korth.) Rehder	+	+	W	
Lithocarpus hystrix (Korth.) Rehder		+		1
Lithocarpus lucidus (Roxb.) Rehder	+	+		
Lithocarpus sundaicus (Blume) Rehder	+	+		
Lithocarpus wallichianus (Lindl. *ex* Hance) Rehder		+		
Quercus argentata Korth.		+		4
FLACOURTIACEAE				
Casearia capitellata Blume		+		
Casearia clarkei King		+		
Casearia lobbiana Turcz.		+	N	1
Flacourtia rukam Zoll. & Moritzi	+	+	N	
Homalium grandiflorum Benth.		+		
Osmelia maingayi King		+	N	
Osmelia philippina (Turcz.) Benth	+	+		
Ryparosa hullettii King		+		
FLAGELLARIACEAE				
Flagellaria indica L.	+	+	N	

Species	R	H	P	S
GESNERIACEAE				
Aeschynanthus albidus (Blume) Steud.	+			
Aeschynanthus parvifolius R. Br.			N	
Aeschynanthus radicans Jack				2
Aeschynanthus wallichii R. Br.			NT	
Cyrtandra pendula Blume		+		
Didymocarpus platypus C.B. Clarke				1,2
GLEICHENIACEAE				
Dicranopteris curranii Copel.			F	
Dicranopteris linearis (Burm.*f.*) Underw.			F	1
Sticherus truncatus (Willd.) Nakai	+		F	
GNETACEAE				
Gnetum gnemon L.	+	+		
Gnetum gnemonoides Brongn.	+	+		
Gnetum macrostachyum Hook.*f.*	+	+		
Gnetum microcarpum Blume	+	+	C	
GRAMINEAE				
Bambusa vulgaris Schrad. *ex* Wendl.			T	
Centotheca lappacea (L.) Desv.	+	+		
Chrysopogon aciculatus (Retz.) Trin.				1
Coix lacryma-jobi L.	+	+		
Cyrtococcum accrescens (Trin.) Stapf		+		
Cyrtococcum oxyphyllum (Steud) Stapf		+		
Digitaria longiflora (Retz.) Pers.		+		
Eragrostis atrovirens (Desf.) Trin. *ex* Steud.		+		
Eragrostis cumingii Steud.		+		
Eragrostis unioloides (Retz.) Nees *ex* Steud.		+		
Gigantochloa ligulata Gamble			T	
Imperata cylindrica (L.) P. Beauv.	+			
Isachne globosa (Thunb.) Kuntze	+			
Isachne pulchella Roth *ex* Roem. & Schult.	+			
Ischaemum ciliare Retz.		+		
Ischaemum timorense Kunth		+		

Species	R	H	P	S
Leptaspis urceolata (Roxb.) R. Br.	+	+	NT	
Lophatherum gracile Brongn.		+		1
Panicum repens L.		+		
Paspalum scrobiculatum L.		+		
Pogonatherum crinitum (Thunb. *ex* Murr.) Kunth				1
Schizostachyum gracile (Munro) Holttum			T	
Schizostachyum latifolium Gamble			T	
Schizostachyum zollingeri Steud.	+			
Soejatmia ridleyi (Gamble) K.M. Wong		+	T	1
GUTTIFERAE				
Calophyllum calaba L.			W	
Calophyllum costulatum M.R. Hend. & Wyatt-Sm.				2
Calophyllum dispar P.F. Stevens	+			
Calophyllum ferrugineum Ridl.	+		CNW	
Calophyllum lanigerum Miq.	+			
Calophyllum macrocarpum Hook.*f.*	+			
Calophyllum pulcherrimum Wall. *ex* Choisy	+		CW	
Calophyllum rigidum Miq.	+			
Calophyllum rubiginosum M.R. Hend. & Wyatt-Sm.	+		NW	
Calophyllum rufigemmatum M.R. Hend. & Wyatt-Sm.	+			2
Calophyllum soulattri Burm.*f.*				1
Calophyllum sundaicum P.F. Stevens	+			
Calophyllum tetrapterum Miq.	+		CN	
Calophyllum teysmannii Miq.	+	+	CN	
Calophyllum wallichianum Planch. & Triana	+	+	CNW	
Cratoxylum arborescens (Vahl) Blume	+	+	N	
Cratoxylum cochinchinense (Lour.) Blume	+	+	CN	
Cratoxylum formosum (Jack) Dyer	+		NW	
Cratoxylum maingayi Dyer	+	+		
Garcinia atroviridis Griff. *ex* T. Anderson	+			
Garcinia eugeniifolia Wall. *ex* T. Anderson	+	+	C	
Garcinia forbesii King	+	+	N	
Garcinia griffithii T. Anderson	+	+	C	
Garcinia hombroniana Pierre		+	W	4
Garcinia maingayi Hook.*f.*	+			

Species	R	H	P	S
Garcinia nervosa Miq.	+	+		
Garcinia nigrolineata Planch. *ex* T. Anderson		+	NW	4
Garcinia parvifolia (Miq.) Miq.	+	+	C	
Garcinia rostrata (Hassk.) Miq.			W	1
Garcinia scortechinii King	+		CN	
Garcinia urophylla Scort. *ex* King	+			
Ploiarium alternifolium (Vahl) Melchior	+		W	
HANGUANACEAE				
Hanguana malayana (Jack) Merr.	+	+	N	
HERNANDIACEAE				
Illigera trifoliata (Griff.) Dunn		+		
HYDROCHARITACEAE				
Blyxa japonica (Miq.) Maxim. *ex* Asch. & Gürke				1
Hydrilla verticillata (L.*f.*) Royle	+			
HYMENOPHYLLACEAE				
Cephalomanes javanicum (Blume) Bosch	+			
Cephalomanes obscurum (Blume) K.Iwatsuki	+			
Crepidomanes christii (Copel.) Copel.	+			
Hymenophyllum denticulatum Sw.			F	
Trichomanes motleyi (Bosch) Bosch			N	
Molineria latifolia (Dryand.) Herb. *ex* Kurz	+	+		
ICACINACEAE				
Gomphandra quadrifida (Blume) Sleumer	+	+		
Gonocaryum gracile Miq.		+		1
Iodes cirrhosa Turcz.	+			
Iodes ovalis Blume	+	+		
Iodes velutina King		+		1
Phytocrene bracteata Wall.	+	+	N	
Platea latifolia Blume		+		
Stemonurus malaccensis (Mast.) Sleumer				4
Stemonurus scorpioides Becc.	+	+	N	

Species	R	H	P	S
IRVINGIACEAE				
Irvingia malayana Oliv. *ex* Benn.	+	+	CN	
IXONANTHACEAE				
Ixonanthes icosandra Jack	+	+	CW	
Ixonanthes reticulata Jack	+	+	CW	
LAURACEAE				
Actinodaphne glomerata (Blume) Nees	+	+		
Actinodaphne macrophylla (Blume) Nees		+	N	1
Actinodaphne malaccensis Hook.*f.*	+	+	W	
Actinodaphne pruinosa Nees	+	+		
Alseodaphne bancana Miq.	+	+		
Alseodaphne intermedia Kosterm.	+	+		
Alseodaphne oblanceolata (Merr.) Kosterm.		+		
Beilschmiedia kunstleri Gamble	+		N	2
Beilschmiedia madang Blume	+			2
Cassytha filiformis L.	+			
Cinnamomum iners Reinw.	+			2
Cinnamomum javanicum Blume	+	+		
Cinnamomum sintoc Blume				4
Cryptocarya ferrea Blume	+		W	
Cryptocarya griffithiana Wight		+		
Cryptocarya impressa Miq.	+			2
Cryptocarya kurzii Hook.*f.*		+		
Cryptocarya rugulosa Hook.*f.*	+		W	
Dehaasia incrassata (Jack) Kosterm.	+			
Lindera lucida (Blume) Boerl.	+	+	CN	
Litsea accedens (Blume) Boerl.	+	+	C	
Litsea castanea Hook.*f.*	+	+	W	
Litsea cordata (Jack) Hook.*f.*				2
Litsea costalis (Nees) Kosterm.	+	+	W	
Litsea costata (Blume) Boerl.	+			2
Litsea elliptica Blume	+	+	CW	
Litsea erectinervia Kosterm.	+			2
Litsea ferruginea (Blume) Blume	+	+	N	

Species	R	H	P	S
Litsea firma (Blume) Hook.*f.*	+	+	CN	
Litsea gracilipes Hook.*f.*		+	NW	
Litsea grandis (Wall. *ex* Nees) Hook.*f.*	+	+	CNW	
Litsea lanceolata (Blume) Kosterm.		+		
Litsea lancifolia (Roxb. *ex* Wall.) Hook.*f.*		+		1
Litsea machilifolia Gamble		+	W	3
Litsea maingayi Hook.*f.*	+			
Litsea ridleyi Gamble	+	+		
Litsea robusta Blume	+			
Neolitsea zeylanica (Nees) Merr.	+	+		
Nothaphoebe umbelliflora Blume	+	+	CW	
Phoebe grandis (Nees) Merr.	+	+		
LECYTHIDACEAE				
Barringtonia racemosa (L.) Spreng.		+		
LEEACEAE				
Leea angulata Korth. *ex* Miq.				2
Leea indica (Burm.*f.*) Merr.	+			2
Leea rubra Blume *ex* Spreng.				3
LEGUMINOSAE				
Acacia kekapur I.C. Nielsen		+		
Adenanthera malayana Kosterm.	+	+		
Aganope thyrsiflora (Benth.) Polhill		+	C	3
Albizia splendens Miq.	+	+	N	
Archidendron bubalinum (Jack) I.C. Nielsen				4
Archidendron clypearia (Jack) I.C. Nielsen	+	+	C	
Archidendron contortum (Mart.) I.C. Nielsen		+		4
Archidendron ellipticum (Blume) I.C. Nielsen	+	+	N	
Archidendron globosum (Blume) I.C. Nielsen	+	+		
Archidendron jiringa (Jack) I.C. Nielsen	+	+		
Archidendron microcarpum (Benth.) I.C. Nielsen		+		1
Bauhinia semibifida Roxb.	+	+	C	
Caesalpinia sumatrana Roxb.			T	2
Callerya eriantha (Benth.) Schot		+	N	1

Species	R	H	P	S
Crotalaria retusa L.	+			
Dalbergia hullettii Prain		+		
Dalbergia junghuhnii Benth.		+		
Dalbergia parviflora Roxb.		+		
Dalbergia pseudosissoo Miq.		+		1
Dalbergia velutina Benth.		+		
Derris amoena Benth.	+	+		
Desmodium heterocarpon (L.) DC.	+			
Desmodium heterophyllum (Willd.) DC.		+		
Dialium indum L.	+	+	NW	
Dialium platysepalum Baker	+	+	W	
Entada spiralis Ridl.	+	+		
Koompassia malaccensis Maing. *ex* Benth.	+	+	CNW	
Kunstleria ridleyi Prain		+	N	1
Ormosia bancana (Miq.) Merr.		+		1
Ormosia macrodisca Baker				1
Ormosia sumatrana (Miq.) Prain		+		
Parkia speciosa Hassk.	+		CN	
Saraca indica L.		+		
Sindora coriacea (Baker) Maingay *ex* Prain	+		W	
Sindora velutina Baker			W	
Sindora wallichii Grah. *ex* Benth.			CN	1
Spatholobus ferrugineus (Zoll. & Moritzi) Benth.	+		C	
Spatholobus maingayi Prain *ex* King		+		
Spatholobus ridleyi Prain *ex* King		+		
LENTIBULARIACEAE				
Utricularia aurea Lour.				1
Utricularia bifida L.	+			
Utricularia caerulea L.	+			
Utricularia gibba L.	+			
LINACEAE				
Indorouchera griffithiana (Planch.) Hallier *f.*	+	+	N	
LOGANIACEAE				

Species	R	H	P	S
Fagraea acuminatissima Merr.		+		
Fagraea auriculata Jack			N	1
Fagraea fragrans Roxb.	+			2
Fagraea racemosa Jack *ex* Wall.	+	+	N	
Fagraea ridleyi King & Gamble		+		
Norrisia maior Soler.	+			
Strychnos axillaris Colebr.			C	
Strychnos ignatii Berg.				2
Strychnos maingayi C.B. Clarke				2
LOMARIOPSIDACEAE				
Bolbitis appendiculata (Willd.) K. Iwatsuki			FT	
Bolbitis heteroclita (C. Presl) Ching			F	
Bolbitis singaporensis Holttum			F	
Bolbitis sinuata (C. Presl) Hennipman			F	
Teratophyllum aculeatum (Blume) Mett. *ex* Kuhn	+		F	
Teratophyllum ludens (Fée) Holttum	+		N	
Teratophyllum rotundifoliatum (R. Bonap.) Holttum	+			
LORANTHACEAE				
Amylotheca duthieana (King) Danser		+		
Barathranthus axanthus (Korth.) Miq.		+		
Dendrophthoe pentandra (L.) Miq.	+	+		
Elytranthe albida (Blume) Blume		+		
Elytranthe arnottiana (Korth.) Miq.		+		
Macrosolen cochinchinensis (Lour.) Tiegh.	+	+		
Scurrula ferruginea (Jack) Danser	+			2
LYCOPODIACEAE				
Huperzia nummulariifolia (Blume) Jermy		+		
Huperzia phlegmaria (L.) Rothm.	+		F	
Huperzia squarrosa (G.Frost) Trevis.			N	
Lycopodiella cernua (L.) Pic. Serm.			F	3
MAGNOLIACEAE				
Magnolia candollii (Blume) H. Keng	+	+	NT	

Species	R	H	P	S
Magnolia elegans (Blume) H. Keng	+	+	CW	
Magnolia maingayi King		+		
Magnolia villosa (Miq.) H. Keng		+		
MALPIGHIACEAE				
Aspidopterys concava (Wall.) A. Juss.		+		1
Hiptage sericea Hook.*f.*				1
MALVACEAE				
Sida rhombifolia L.	+	+		
Urena lobata L.		+		1
MARANTACEAE				
Donax grandis (Miq.) K. Schum.		+		3
Phrynium parvum (Ridl.) Holttum	+			
Phrynium villosulum Miq.		+		
Stachyphrynium griffithii (Baker) K. Schum.	+	+		
MARATTIACEAE				
Angiopteris evecta (G. Forst.) Hoffm.			F	
MELASTOMATACEAE				
Diplectria viminalis (Jack) Kuntze			N	
Dissochaeta annulata Hook.*f. ex* Triana		+		
Dissochaeta celebica Blume	+			2
Dissochaeta pallida (Jack) Blume	+			2
Dissochaeta punctulata Hook.*f. ex* Triana		+		
Lijndenia laurina Zoll. & Moritzi				2,4
Macrolenes echinulata (Naudin) Bakh.*f.*				1
Medinilla crassifolia (Reinw. *ex* Blume) Blume			N	
Melastoma malabathricum L.	+			2
Memecylon amplexicaule Roxb.		+		4
Memecylon caeruleum Jack			W	3
Memecylon campanulatum C.B. Clarke		+		4
Memecylon edule Roxb.	+	+		
Memecylon excelsum Blume		+		

Species	R	H	P	S
Memecylon floridum Ridl.	+	+	N	
Memecylon garcinioides Blume		+		
Memecylon globosum Bakh.*f.*		+		
Memecylon lilacinum Zoll. & Moritzi	+	+		
Memecylon megacarpum Furtado	+	+		
Memecylon minutiflorum Miq.			C	4
Memecylon oleifolium Blume		+		
Memecylon paniculatum Jack	+	+		
Memecylon pubescens (C.B. Clarke) King		+		
Pachycentria constricta (Blume) Blume		+	N	
Pachycentria maingayi (C.B. Clarke) J.F. Maxwell	+	+		
Pogonanthera pulverulenta (Jack) Blume		+		
Pternandra coerulescens Jack	+	+	NW	
Pternandra echinata Jack	+	+	CNW	
Pternandra tuberculata (Korth.) M.P. Nayar	+	+		
Sonerila heterostemon Naudin	+		T	
Sonerila moluccana Roxb.		+		
MELIACEAE				
Aglaia cucullata (Roxb.) Pellegr.		+		
Aglaia exstipulata (Griff.) W. Theob.	+	+		
Aglaia leptantha Miq.		+		3
Aglaia leucophylla King	+			
Aglaia macrocarpa (Miq.) Pannell		+		
Aglaia maingayi (Hiern) King	+			
Aglaia malaccensis (Ridl.) Pannell	+	+		
Aglaia odoratissima Blume	+	+		
Aglaia oligophylla Miq.		+		
Aglaia rubiginosa (Hiern) Pannell	+	+	N	
Aglaia rufinervis (Blume) Bentv.		+	W	3
Aglaia simplicifolia (Bedd.) Harms				3
Aglaia spectabilis (Miq.) S.S. Jain & Bennet				4
Aglaia tomentosa Teijsm. & Binn.		+		
Aphanamixis polystachya (Wall.) R. Parker		+	N	1
Chisocheton erythrocarpus Hiern			W	
Chisocheton patens Blume	+	+		

Species	R	H	P	S
Chisocheton pentandrus (Blanco) Merr.	+			2
Chisocheton sarawakanus (C. DC.) Harms.	+			
Dysoxylum acutangulum Miq.		+		
Dysoxylum alliaceum (Blume) Blume		+		
Dysoxylum carolinae Mabb.		+		
Dysoxylum cauliflorum Hiern	+	+	C	
Dysoxylum cyrtobotryum Miq.		+		3
Dysoxylum densiflorum (Blume) Miq.	+			2
Dysoxylum excelsum Blume	+	+		
Dysoxylum flavescens Hiern	+	+		
Pseudoclausena chrysogyne (Miq.) T.P. Clark		+		4
Sandoricum beccarianum Baill.	+	+	N	
Sandoricum koetjape (Burm.*f.*) Merr.	+	+	W	
MELIOSMACEAE				
Meliosma lanceolata Blume	+			2
Meliosma pinnata (Roxb.) Maxim			W	
Meliosma simplicifolia (Roxb.) Walp.	+			
MENISPERMACEAE				
Coscinium fenestratum (Gaertn.) Colebr.		+		
Cyclea laxiflora Miers		+		
Fibraurea tinctoria Lour.	+	+		
Limacia oblonga Hook.*f.* & Thomson				1
Limacia scandens Lour.	+	+		
Stephania capitata (Blume) Spreng.	+	+		
Tinomiscium petiolare Hook.*f.* & Thomson	+	+	C	
Tinospora macrocarpa Diels	+			
MENYANTHACEAE				
Nymphoides indica (L.) Kuntze	+			
MONIMIACEAE				
Kibara coriacea (Blume) Tul.	+			
Matthaea sancta Blume	+			

Species	R	H	P	S
MORACEAE				
Artocarpus anisophyllus Miq.	+	+		
Artocarpus dadah Miq.	+	+		
Artocarpus elasticus Reinw. *ex* Blume	+	+	CN	
Artocarpus fulvicortex F.M. Jarrett	+	+		
Artocarpus gomezianus Wall. *ex* Trécul.	+	+		
Artocarpus hispidus Jarrett		+		4
Artocarpus kemando Miq.	+	+	NW	
Artocarpus lanceifolius Roxb.	+	+	W	
Artocarpus lowii King	+	+		
Artocarpus maingayi King		+		
Artocarpus nitidus Trécul.	+		N	
Artocarpus rigidus Blume	+	+	CW	
Artocarpus scortechinii King	+	+	NW	
Ficus annulata Blume		+		
Ficus apiocarpa Miq.	+	+	N	
Ficus aurantiacea Griff.	+	+		
Ficus aurata Miq.	+	+		
Ficus binnendykii Miq.	+	+	N	
Ficus bracteata Wall. *ex* Miq.	+	+	N	
Ficus caulocarpa Miq.				2
Ficus chartacea Wall. *ex* King	+	+		
Ficus consociata Blume	+	+	N	
Ficus delosyce Corner		+		
Ficus deltoidea Jack	+			
Ficus dubia Wall. *ex* King		+	W	
Ficus excavata King			N	
Ficus fistulosa Reinw. *ex* Blume	+	+	N	
Ficus glandulifera (Wall. *ex* Miq.) King	+	+		
Ficus globosa Blume	+	+	N	
Ficus grossularioides Burm.*f.*	+	+		
Ficus heteropleura Blume	+	+		
Ficus kerkhovenii Valeton	+	+		
Ficus laevis Blume	+			2
Ficus lamponga Miq.	+	+		
Ficus microcarpa L.*f.*				1,2

Species	R	H	P	S
Ficus microsyce Ridl.		+	N	1
Ficus obscura Blume		+	N	
Ficus pellucidopunctata Griff.		+	N	
Ficus pisocarpa Blume	+			2
Ficus recurva Blume		+	N	
Ficus retusa L.		+		3
Ficus ruginervia Corner		+		
Ficus sagittata Vahl	+		N	
Ficus schwarzii Koord.		+		
Ficus scortechinii King	+	+		
Ficus sinuata Thunb.	+			
Ficus subgelderi Corner		+		
Ficus sumatrana Miq.		+		
Ficus sundaica Blume	+	+	N	
Ficus superba Miq.				1
Ficus trichocarpa Blume	+		N	
Ficus variegata Blume		+		1
Ficus vasculosa Wall. *ex* Miq.		+		
Ficus villosa Blume	+		N	
Ficus virens Aiton		+		
Ficus xylophylla Wall. *ex* Miq.		+	N	
Parartocarpus bracteatus (King) Becc.	+	+		
Streblus elongatus (Miq.) Corner	+	+	CNW	
MYRICACEAE				
Myrica esculenta Buch.-Ham.	+			2
MYRISTICACEAE				
Endocomia canarioides (King) W.J. de Wilde		+		
Gymnacranthera bancana (Miq.) J. Sinclair	+	+	N	
Gymnacranthera farquhariana (Hook.*f.* & Thomson) Warb.	+	+	NW	
Gymnacranthera forbesii (King) Warb.	+	+	W	
Horsfieldia brachiata (King) Warb.			W	4
Horsfieldia crassifolia (Hook.*f.* & Thomson) Warb.	+	+	N	
Horsfieldia grandis (Hook.*f.*) Warb.		+	N	
Horsfieldia irya (Gaertn.) Warb.				2

Species	R	H	P	S
Horsfieldia polyspherula (Hook.*f.* emend King) J. Sinclair	+	+	N	
Horsfieldia punctatifolia J. Sinclair	+			
Horsfieldia sucosa (King) Warb.	+	+	N	
Horsfieldia superba (Hook.*f.* & Thomson) Warb.	+	+	NW	
Horsfieldia wallichii (Hook.*f.* & Thomson) Warb.	+	+		
Knema communis J. Sinclair	+	+		
Knema conferta (King) Warb.	+	+	N	
Knema curtisii (King) Warb.	+	+	N	
Knema furfuracea (Hook.*f.* & Thomson) Warb.	+			
Knema glaucescens Jack		+	N	
Knema hookeriana (Wall. *ex* Hook.*f.* & Thomson) Warb.	+	+	W	
Knema intermedia (Blume) Warb.	+	+	CNW	
Knema latericia Elmer	+	+	C	
Knema laurina (Blume) Warb.	+			2
Knema malayana Warb.	+	+	N	
Knema patentinervia (J. Sinclair) W.J. de Wilde				4
Myristica cinnamomea King	+	+	CNW	
Myristica crassa King		+		3
Myristica elliptica Hook.*f.* & Thomson	+	+	N	
Myristica iners Blume	+	+	N	
Myristica lowiana King	+	+	N	
Myristica maingayi Hook.*f.*	+	+		
Myristica maxima Warb.		+		
MYRSINACEAE				
Ardisia colorata Roxb.	+	+		
Ardisia crassa C.B. Clarke				4
Ardisia lanceolata Roxb.		+		
Ardisia miqueliana Scheff.	+	+		
Ardisia sessilis Scheff.		+		
Ardisia singaporensis Ridl.	+			
Ardisia teysmanniana Scheff.		+	CW	3
Ardisia tuberculata Wall. *ex* A. DC.		+	W	
Ardisia villosa Roxb.	+			
Embelia canescens Jack	+	+		
Embelia coriacea Wall. *ex* A. DC.		+	N	

Species	R	H	P	S
Embelia dasythyrsa Miq.		+		
Embelia ribes Burm.	+	+	C	
Grenacheria lampani (Scheff.) Mez	+	+		
Labisia pumila (Blume) Fern.-Vill	+	+	T	
Maesa ramentacea Wall. *ex* Roxb.	+	+	NW	
MYRTACEAE				
Acmena acuminatissima (Blume) Merr. & L.M. Perry	+	+	N	
Decaspermum parviflorum (Lam.) A.J. Scott	+	+	N	
*Eugenia sp.*8		+		
*Eugenia sp.*39		+		
Melaleuca cajuputi Powell		+		
Rhodamnia cinerea Jack	+	+	CW	
Rhodomyrtus tomentosa (Aiton) Hassk.	+	+		
Syzygium attenuatum (Miq.) Merr. & L.M. Perry		+		
Syzygium borneense (Miq.) Miq.	+	+	N	
Syzygium cerinum (M.R. Hend.) I.M. Turner	+	+	N	
Syzygium chloranthum (Duthie) Merr. & L.M. Perry	+	+	W	
Syzygium cinereum (Kurz) P. Chantaranothai & J. Parn.	+	+		
Syzygium claviflorum (Roxb.) Wall. *ex* A.M. Cowan & Cowan				1
Syzygium duthieanum (King) Masam.	+	+		
Syzygium filiforme (Wall. *ex* Duthie) P. Chantaranothai &	+	+	W	
Syzygium flosculiferum (M.R. Hend.) Sreek.				1
Syzygium glaucum (King) P. Chantaranothai & J. Parn.	+	+	W	
Syzygium gracile (Korth.) Amsh.		+		1
Syzygium grande (Wight) Walp.	+	+	C	
Syzygium griffithii (Duthie) Merr. & L.M. Perry				2
Syzygium inophyllum DC.		+		4
Syzygium kunstleri (King) Bahadur & R.C. Gaur			N	
Syzygium leptostemon (Korth.) Merr. & L.M. Perry		+		
Syzygium leucoxylum Korth.				1
Syzygium lineatum (DC.) Merr. & L.M. Perry	+	+	CN	
Syzygium linoceroides (King) I.M. Turner			W	4
Syzygium maingayi P. Chantaranothai & J. Parn.	+	+		
Syzygium muelleri (Miq.) Miq.	+			
Syzygium nemestrinum (M.R. Hend.) I.M. Turner	+	+	N	

Species	R	H	P	S
Syzygium ngadimanianum (M.R. Hend.) I.M. Turner	+	+	W	
Syzygium nigricans (King) Merr. & L.M. Perry	+	+		
Syzygium oblatum (Roxb.) Wall. *ex* A.M. Cowan & Cowan		+		
Syzygium pachyphyllum (Kurz) Merr. & L.M. Perry	+	+	N	
Syzygium palembanicum Miq.		+	W	1
Syzygium papillosum (Duthie) Merr. & L.M. Perry	+	+	N	
Syzygium pauper (Ridl.) I.M. Turner	+	+		
Syzygium pendens (Duthie) I.M. Turner	+	+		
Syzygium polyanthum (Wight) Walp.	+	+		
Syzygium pseudocrenulatum (M.R. Hend.) I.M. Turner		+	N	
Syzygium pseudoformosum (King) Merr. & L.M. Perry		+		3
Syzygium pustulatum (Duthie) Merr.	+	+		
Syzygium pycnanthum Merr. & L.M. Perry		+		4
Syzygium pyrifolium (Blume) DC.	+	+	N	
Syzygium ridleyi (King) P. Chantaranothai & J. Parn.	+	+		
Syzygium rugosum Korth.		+	W	
Syzygium scortechinii (King) P. Chantaranothai & J. Parn.		+		
Syzygium singaporense (King) Airy Shaw	+	+	N	
Syzygium skiophilum (Duthie) Airy Shaw	+			
Syzygium subdecussatum (Wall. *ex* Duthie) I.M. Turner	+	+	W	
Syzygium syzygioides (Miq.) Merr. & L.M. Perry		+		1
Syzygium zeylanicum (L.) DC.	+	+		
Tristaniopsis merguensis (Griff.) Peter G. Wilson & J.T. Water	+		W	
Tristaniopsis whiteana (Griff.) Peter G. Wilson & J.T. Water		+		
HYDROCHARITACEAE				
Najas indica (Willd.) Cham.	+			
Najas malesiana W.J. de Wilde	+			
NEPENTHACEAE				
Nepenthes ampullaria Jack	+	+	N	
Nepenthes gracilis Korth.	+	+	N	
Nepenthes hookerana Lindl.		+		3
Nepenthes rafflesiana Jack	+		N	
Nepenthes trichocarpa Miq.			T	

Species	R	H	P	S
NYCTAGINACEAE				
Boerhavia diffusa L.				1
NYMPHAEACEAE				
Barclaya motleyi Hook.*f.*		+	N	1
OCHNACEAE				
Brackenridgea hookeri (Planch.) A. Gray	+	+		
Brackenridgea palustris Bartell.		+		
Campylospermum serratum (Gaertn.) Bittrich & M.C.E. Amaral	+	+	CW	
Euthemis leucocarpa Jack		+		
OLACACEAE				
Anacolosa frutescens (Blume) Blume		+		
Erythropalum scandens Blume	+	+		
Ochanostachys amentacea Mast.	+	+	CW	
Scorodocarpus borneensis (Baill.) Becc.	+	+	W	
Strombosia ceylanica Gardn.	+	+	NW	
Strombosia javanica Blume	+	+		
OLEACEAE				
Chionanthus ramiflorus Roxb.		+	N	
Jasminum elongatum (Bergius) Willd.		+		
OLEANDRACEAE				
Nephrolepis acutifolia (Desv.) H. Christ.	+			
Nephrolepis auriculata (L.) Trimen	+			
ONAGRACEAE				
Ludwigia adscendens (L.) H. Hara	+	+		
Ludwigia hyssopifolia (G. Don) Exell	+			
Ludwigia octovalvis (Jacq.) P.H. Raven	+			
Ludwigia prostrata Roxb.				3
OPILIACEAE				
Champereia manillana (Blume) Merr.	+	+	C	

Species	R	H	P	S
Lepionurus sylvestris Blume	+			
ORCHIDACEAE				
Adenoncos sumatrana J.J. Sm.		+		
Agrostophyllum bicuspidatum J.J. Sm.		+	N	
Agrostophyllum majus Hook.*f.*		+		
Anoectochilus geniculatus Ridl.		+	N	
Aphyllorchis pallida Blume		+		
Apostasia nuda R. Br.		+		
Appendicula cornuta Blume		+		
Appendicula lucida Ridl.		+	N	
Appendicula uncata Ridl.		+		
Arundina graminifolia (D. Don) Hochr.	+	+		
Bromheadia aporoides Rchb.*f.*		+		
Bromheadia finlaysoniana (Lindl.) Miq.	+	+		
Bulbophyllum macranthum Lindl.	+		T	
Bulbophyllum macrochilum Rolfe		+		
Bulbophyllum medusae (Lindl.) Rchb.*f.*		+		
Bulbophyllum membranaceum Teijsm. & Binn.				1
Bulbophyllum ovalifolium (Blume) Lindl.		+		
Bulbophyllum patens King *ex* Hook.*f.*		+		
Bulbophyllum pileatum Lindl.		+		
Bulbophyllum purpurascens Teijsm. & Binn.		+		
Bulbophyllum sessile (J. König) J.J. Sm.		+		
Bulbophyllum vaginatum (Lindl.) Rchb.*f.*	+			
Calanthe pulchra (Blume) Lindl.	+	+	N	
Cirrhopetalum concinnum Hook.*f.*				1
Cirrhopetalum gusdorfii (J.J. Sm.) Garay & al.	+			
Claderia viridiflora Hook.*f.*	+	+	N	
Coelogyne cumingii Lindl.				2
Corymborkis veratrifolia (Reinw.) Blume		+		
Cryptostylis arachnites (Blume) Hassk.		+		
Cymbidium finlaysonianum Lindl.	+	+		
Cystorchis variegata Blume		+		1
Dendrobium crumenatum Sw.	+	+	N	
Dendrobium indivisum (Blume) Miq.		+		

Species	R	H	P	S
Dendrobium pulchellum Roxb. *ex* Lindl.		+		
Dendrobium setifolium Ridl.		+		
Dendrobium subulatum (Blume) Lindl.		+		
Didymoplexis pallens Griff.		+		1
Dilochia wallichii Lindl.				1
Dipodium scandens (Blume) J.J. Sm.				1
Eria pulchella Lindl.		+		
Eulophia graminea Lindl.	+			
Eulophia spectabilis (Dennst.) Suresh		+	N	1
Flickingeria fimbriata (Blume) A.D. Hawkes		+		
Galeola nudifolia Lour.			N	
Gastrodia javanica (Blume) Lindl.		+		1
Grammatophyllum speciosum Blume				2
Hetaeria nitida Ridl.		+		
Hetaeria obliqua Blume		+		
Hylophila mollis Lindl.		+	N	1
Lecanorchis malaccensis Ridl.	+	+		
Liparis ferruginea Lindl.		+		1
Liparis tricallosa Rchb.*f.*		+		
Liparis wrayi Hook.*f.*		+	N	
Malaxis latifolia Sm.		+		
Malaxis micrantha (Hook.*f.*) Kuntze		+		
Microsaccus javensis Blume		+		
Nephelaphyllum pulchrum Blume	+	+		
Nervilia punctata (Blume) Makino		+	N	
Neuwiedia griffithii Rchb.*f.*		+		
Neuwiedia veratrifolia Blume		+		
Oberonia ciliolata Hook.*f.*				2
Oberonia dissitiflora Ridl.		+		
Oberonia stenophylla Ridl.		+		
Peristylus candidus J.J. Sm.		+		
Peristylus lacertiferus (Lindl.) J.J. Sm.		+		
Phaius tankervilleae (Banks *ex* L'Heritier) Blume				1
Plocoglottis gigantea (Hook.*f.*) J.J. Sm.	+	+		
Plocoglottis javanica Blume	+	+	N	
Plocoglottis lowii Rchb.*f.*				1

Species	R	H	P	S
Podochilus microphyllus Lindl.		+		
Pomatocalpa latifolium (Lindl.) J.J. Sm.				1
Pteroceras pallidum (Blume) Holttum	+			2
Spathoglottis plicata Blume	+	+		
Stereosandra javanica Blume		+		
Taeniophyllum filiforme J.J. Sm.			N	
Taeniophyllum obtusum Blume	+		T	
Thrixspermum amplexicaule (Blume) Rchb.*f.*				1
Thrixspermum calceolus (Lindl.) Rchb.*f.*		+		
Thrixspermum ridleyanum Schltr.		+		
Thrixspermum trichoglottis (Hook.*f.*) Kuntze	+	+	T	
Trichotosia gracilis (Hook.*f.*) Kraenzl.				2
Trichotosia velutina (Lodd *ex* Lindl.) Kraenzl.			N	
Tropidia curculigoides Lindl.		+		
Vanilla griffithii Rchb.*f.*	+	+		
Vrydagzynea albida (Blume) Blume		+		
Vrydagzynea lancifolia Ridl.		+		
Vrydagzynea tristriata Ridl.		+		
Zeuxine clandestina Blume		+		1
OXALIDACEAE				
Dapania racemosa Korth.			N	
Sarcotheca griffithii (Planch. *ex* Hook.*f.*) Hallier *f.*	+	+		
Sarcotheca laxa (Ridl.) Kunth	+			
PALMAE				
Calamus diepenhorstii Miq.	+	+		
Calamus insignis Griff.	+	+		
Calamus javensis Blume				2,4
Calamus laevigatus Mart.		+		4
Calamus lobbianus Becc.	+	+		
Calamus ornatus Blume		+		
Calamus oxleyanus Teijsm. & Binn.	+	+		
Calamus paspalanthus Becc.		+		
Calamus ridleyanus Becc.		+		
Caryota mitis Lour.	+	+		

Species	R	H	P	S
Daemonorops angustifolia (Griff.) Mart.	+	+		
Daemonorops didymophylla Becc.	+	+		
Daemonorops geniculata (Griff.) Mart.	+			
Daemonorops grandis (Griff.) Mart.	+	+		
Daemonorops hystrix (Griff.) Mart.	+	+		
Daemonorops kunstleri Becc.		+		1
Daemonorops leptopus (Griff.) Mart.	+	+		
Daemonorops lewisiana (Griff.) Mart.		+		
Daemonorops longipes (Griff.) Mart.	+	+		
Daemonorops micracantha (Griff.) Becc.		+		1
Daemonorops periacantha Miq.	+	+		
Daemonorops sabut Becc.		+		1
Eleiodoxa conferta (Griff.) Burret		+		1
Iguanura wallichiana (Wall. *ex* Mart.) Hook.*f.*	+			2
Korthalsia echinometra Becc.	+	+		
Korthalsia flagellaris Miq.	+			
Korthalsia laciniosa (Griff.) Mart.		+		
Korthalsia rigida Blume		+		
Korthalsia rostrata Blume		+		4
Korthalsia scortechinii Becc.		+		1
Licuala ferruginea Becc.	+	+		
Myrialepis paradoxa (Kurz) J. Dransf.				1.2
Nenga pumila (Mart.) H. Wendl.	+		N	
Oncosperma horridum (Griff.) Scheff.	+		N	
Orania sylvicola (Griff.) H.E. Moore		+		
Pinanga limosa Ridl.		+		
Pinanga malaiana (Mart.) Scheff.	+			2
Pinanga pectinata Becc.				2
Pinanga simplicifrons (Miq.) Becc.				1
Plectocomia elongata Mart. *ex* Blume	+	+		
Rhopaloblaste singaporensis (Becc.) Hook.*f.*	+	+	T	
Salacca affinis Griff.		+		
PANDACEAE				
Galearia fulva (Tul.) Miq.	+	+	N	
Galearia maingayi Hook.*f.*	+			

Species	R	H	P	S
Microdesmis caseariifolia Planch.	+	+		
PANDANACEAE				
Freycinetia angustifolia Blume	+	+	N	
Freycinetia confusa Ridl.			N	
Freycinetia corneri B.C. Stone			N	
Freycinetia imbricata Blume	+			2
Freycinetia javanica Blume	+	+	N	
Pandanus atrocarpus Griff.	+	+	N	
Pandanus houllettii Carriere	+	+		
Pandanus kamiae B.C.Stone			N	
Pandanus monotheca Mart.	+	+		
Pandanus motleyanus Solms	+			
Pandanus parvus Ridl.	+			
Pandanus scortechinii Mart.	+			
Pandanus yvanii Solms		+		1
PARKERIACEAE				
Ceratopteris thalictroides (L.) Brongn.	+			
PASSIFLORACEAE				
Adenia macrophylla (Blume) Koord.	+	+	T	
PENTAPHRAGMATACEAE				
Pentaphragma ellipticum Poulsen		+	T	3
PHORMIACEAE				
Dianella ensifolia (L.) DC.	+		N	
PIPERACEAE				
Piper caninum Blume	+			2
Piper flavimarginatum C. DC.		+		
Piper macropiper Pennant	+	+	N	
Piper maingayi Hook.*f.*				2
Piper muricatum Blume	+			2
Piper pachyphyllum Hook.*f.*				2

Species	R	H	P	S
Piper pedicellosum Wall.	+			
Piper porphyrophyllum N.E. Br.				2
Piper sarmentosum Roxb.				1
PODOCARPACEAE				
Nageia wallichiana (Presl) Kuntze			N	1
Podocarpus polystachyus R. Br. *ex* Endl.	+			
POLYGALACEAE				
Salomonia cantoniensis Lour.	+			
Xanthophyllum affine Korth. *ex* Miq.	+	+	N	
Xanthophyllum amoenum Chodat	+	+		
Xanthophyllum discolor Chodat		+		
Xanthophyllum ellipticum Korth. *ex* Miq.	+	+	W	
Xanthophyllum eurhynchum Miq.	+	+		
Xanthophyllum griffithii Hook.*f. ex* A.W. Benn.	+	+		
Xanthophyllum obscurum A.W. Benn.	+	+		
Xanthophyllum stipitatum A.W. Benn.	+	+	W	
Xanthophyllum vitellinum (Blume) Dietr.	+	+		
POLYGONACEAE				
Persicaria barbata (L.) H. Hara	+			
POLYPODIACEAE				
Drynaria quercifolia (L.) J.J. Sm.	+		N	
Lecanopteris sinuosa (Wall. *ex* Hook.) Copel.	+			
Microsorum punctatum (L.) Copel.		+		
Phymatosorus nigrescens (Blume) Pic. Serm.			F	
Phymatosorus scolopendria (Burm.*f.*) Pic. Serm.				1
Platycerium coronarium (D. König *ex* O.F. Müll) Desv.	+		FN	
Platycerium ridleyi H. Christ			F	
Pyrrosia longifolia (Burm.) C.V. Morton	+			
Pyrrosia piloselloides (L.) M.G. Price	+			
PONTEDERIACEAE				
Monochoria hastata (L.) Solms	+			

Species	R	H	P	S
Monochoria vaginalis (Burm.*f.*) Kunth	+			
PROTEACEAE				
Helicia excelsa (Roxb.) Blume		+		
Helicia petiolaris Benn.	+			
Helicia robusta (Roxb.) R. Br. *ex* Wall.				2
PSILOTACEAE				
Psilotum nudum (L.) P. Beauv.				1
PTERIDACEAE				
Pteris ensiformis Burm.*f.*	+			
Pteris vittata L.				1
RHAMNACEAE				
Ventilago malaccensis Ridl.		+	C	1
Ziziphus calophylla Wall. *ex* Hook.*f.*		+	W	3
Ziziphus elegans Wall.		+	N	3
Ziziphus horsfieldii Miq.		+		
RHIZOPHORACEAE				
Carallia brachiata (Lour.) Merr.	+	+	N	
Gynotroches axillaris Blume	+	+	CNW	
Pellacalyx axillaris Korth.	+	+	NW	
Pellacalyx saccardianus Scort.	+	+	CW	
ROSACEAE				
Prunus arborea (Blume) Kalkman	+		N	
Prunus grisea (Blume) Kalkman		+	N	
Prunus polystachya (Hook.*f.*) Kalkman	+	+	CW	
Rubus moluccanus L.	+	+		
RUBIACEAE				
Aidia densiflora (Wall.) Masam.	+	+	NW	
Borreria laevicaulis (Miq.) Ridl.	+			
Canthium confertum Korth.	+	+		

Species	R	H	P	S
Canthium glabrum Blume	+	+		
Canthium horridum Blume	+	+		
Canthium molle King & Gamble		+		
Chassalia chartacea Craib	+			
Chassalia curviflora (Wall.) Thw.	+			2
Chassalia pubescens Ridl.				2
Coelospermum truncatum (Wall.) Baill. *ex* K. Schum.		+		2
Coptosapelta griffithii Hook.*f.*		+		
Coptosapelta parviflora Ridl.				2
Coptosapelta tomentosa (Blume) Valeton *ex* K. Heyne				2
Diplospora malaccensis Hook.*f.*	+	+	W	
Gaertnera grisea Hook.*f. ex* C.B. Clarke	+		C	
Gaertnera obesa Hook.*f. ex* C.B. Clarke	+			
Gaertnera viminea Hook.*f. ex* C.B. Clarke	+			2
Gardenia griffithii Hook.*f.*	+	+	C	
Gardenia tubifera Wall.	+	+		
Gardeniopsis longifolia Miq.				2
Geophila pilosa H. Pearson		+		
Gynochthodes coriacea Blume		+		1
Gynochthodes sublanceolata Miq.	+	+		
Hedyotis auricularia L.	+			2
Hedyotis capitellata Wall. *ex* G. Don	+			
Hedyotis herbacea L.	+			
Hedyotis philippinensis (Willd. *ex* Spreng.) Merr. *ex* C.B. Rob.	+	+		
Hedyotis pinifolia Wall. *ex* G. Don		+		
Hydnophytum formicarum Jack	+	+	NT	
Ixora concinna Hook.*f.*		+		
Ixora congesta Roxb.	+	+	N	
Ixora javanica (Blume) DC.	+	+		
Ixora lobbii King & Gamble	+	+		
Ixora pendula Jack	+	+		
Ixora umbellata Koord & Valeton		+		
Jackiopsis ornata (Wall.) Ridsdale	+	+	N	
Lasianthus appressus Hook.*f.*	+			
Lasianthus attenuatus Jack	+	+		
Lasianthus constrictus Wight	+			

Species	R	H	P	S
Lasianthus cyanocarpus Jack	+			
Lasianthus densifolius Miq.	+	+		
Lasianthus ellipticus Wight		+		4
Lasianthus griffithii Wight	+		N	
Lasianthus maingayi Hook.*f.*		+		
Lasianthus perakensis King & Gamble	+	+		
Lasianthus ridleyi King & Gamble		+	T	1
Lasianthus scabridus King & Gamble	+			
Lasianthus stipularis Blume		+		
Lasianthus tomentosus Blume	+			
Lucinaea membranacea King	+	+		
Morinda ridleyi (King & Gamble) Ridl.		+		
Morinda rigida Miq.		+		
Morinda umbellata L.	+	+		
Mussaenda glabra Vahl	+	+		
Mussaenda mutabilis Hook.*f.*		+		
Mussaendopsis beccariana Baill.	+		N	
Mycetia malayana (Wall. *ex* Ridl.) Craib		+		
Myrmecodia tuberosa Jack			N	1
Nauclea officinalis (Pierre *ex* Pit.) Merr. & Chun	+	+	W	
Nauclea subdita (Korth.) Steud.				2
Ophiorrhiza singaporensis Ridl.	+	+		
Oxyceros fragrantissima (Ridl.) K.M. Wong		+	T	
Oxyceros longiflora (Lam.) T. Yamaz.				1
Oxyceros penangiana (King & Gamble) Tirveng.				2
Oxyceros scandens (Blume) Tirveng.				2,3
Paederia foetida L.	+			
Paederia verticillata Blume		+		
Pavetta wallichiana Steud.	+			2
Pertusadina eurhyncha (Miq.) Ridsdale	+	+	W	
Porterandia anisophylla (Jack *ex* Roxb.) Ridl.	+	+	CW	
Prismatomeris glabra (Korth.) Valeton		+	T	4
Prismatomeris tetrandra (Roxb.) K. Schum.			C	1
Psychotria cantleyi Ridl.			T	
Psychotria griffithii Hook.*f.*		+		1
Psychotria helferiana Kurz	+	+		

Species	R	H	P	S
Psychotria maingayi Hook.*f.*	+		N	
Psychotria malayana Jack		+		
Psychotria obovata Wall.	+	+		
Psychotria ovoidea Wall.	+	+		
Psychotria penangiana Hook.*f.*	+	+		
Psychotria ridleyi King & Gamble				1,2
Psychotria rostrata Blume	+	+		
Psychotria sarmentosa Blume	+			
Psychotria singapurensis (Ridl.) I.M. Turner	+			
Psydrax maingayi (Hook. *f.*) Bridson				4
*Psydrax sp.*10	+			
*Psydrax sp.*11	+			
Rothmannia macrophylla (R. Br. *ex* Hook.*f.*) Bremek.	+	+	NT	
Saprosma glomerulata King & Gamble		+		1
Tarenna adpressa (King) Merr.			N	
Tarenna costata (Miq.) Merr.	+	+		
Tarenna fragrans (Nees) Koord. & Valeton				1
Tarenna mollis (Wall. *ex* Hook.*f.*) B.L. Rob.	+			
Tarenna odorata (Roxb.) B.L. Rob.	+			2
Tarenna stellulata (Hook.*f.*) Ridl.	+			
Timonius flavescens (Jack) Baker		+	CN	
Timonius wallichianus (Korth.) Valeton	+	+	CNW	
Uncaria acida (W. Hunt.) Roxb.			N	
Uncaria attenuata Korth.				2
Uncaria callophylla Blume *ex* Korth.		+		3
Uncaria cordata (Lour.) Merr.	+	+		
Uncaria lanosa Wall.	+	+		
Uncaria longiflora (Poir.) Merr.	+	+		
Uncaria roxburghiana Korth.				2
Urophyllum blumeanum (Wight) Hook.*f.*	+	+		
Urophyllum glabrum Wall.	+	+	NW	
Urophyllum griffithianum (Wight) Hook.*f.*	+			
Urophyllum hirsutum (Wight) Hook.*f.*	+	+		
*Urophyllum sp.*2	+	+		
Urophyllum streptopodium Wall. *ex* Hook.*f.*	+	+	CN	

Species	R	H	P	S
RUTACEAE				
Clausena excavata Burm.*f.*	+			
Glycosmis chlorosperma Spreng.	+	+	C	
Luvunga crassifolia Tanaka	+			
Maclurodendron porteri (Hook.*f.*) T.G. Hartley	+	+		
Melicope glabra (Blume) T.G. Hartley	+	+	CW	
Melicope hookeri T.G. Hartley		+		
Melicope lunu-ankenda (Gaertn.) T.G. Hartley		+		1
Paramignya scandens (Griff.) Craib		+		
SANTALACEAE				
Dendrotrophe varians (Blume) Miq.	+	+		
Scleropyrum pentandrum (Dennst.) Mabb.	+	+		
SAPINDACEAE				
Cardiospermum halicacabum L.	+	+		
Guioa pleuropteris (Blume) Radlk.	+	+		
Guioa pubescens (Zoll. & Moritzi) Radlk.	+	+	C	
Lepisanthes rubiginosa (Roxb.) Leenh.				1
Lepisanthes senegalensis (Poir.) Leenh.	+			
Mischocarpus pentapetalus (Roxb.) Radlk.				2
Nephelium cuspidatum Blume	+			2
Nephelium lappaceum L.	+	+	NW	
Nephelium laurinum Blume		+	NW	
Nephelium maingayi Hiern		+	W	
Nephelium ramboutan-ake (Labill.) Leenh.		+		4
Pometia pinnata J.R. Forst.	+	+	NW	
Trigonachras acuta (Hiern) Radlk.		+		1
Xerospermum laevigatum Radlk.		+		
Xerospermum noronhianum (Blume) Blume	+	+	CW	
SAPOTACEAE				
Chrysophyllum roxburghii G. Don		+		1
Madhuca kingiana (Brace *ex* King & Gamble) H.J. Lam	+		CW	
Madhuca korthalsii (Pierre *ex* Burck) H.J. Lam	+			
Madhuca malaccensis (C.B. Clarke) H.J. Lam	+	+		

Species	R	H	P	S
Madhuca motleyana (de Vriese) J.F. Macbr.	+		N	
Madhuca sericea (Miq.) H.J. Lam	+	+		
Palaquium gutta (Hook.*f.*) Baill.		+	CW	3
Palaquium hexandrum (Griff.) Baill.	+	+	NW	
Palaquium microphyllum King & Gamble	+	+	CW	
Palaquium obovatum (Griff.) Engl.	+	+	W	
Palaquium rostratum (Miq.) Burck	+	+	N	
Palaquium semaram H.J. Lam			W	
Palaquium xanthochymum (de Vriese) Pierre *ex* Burck	+	+	N	
Payena lucida (G. Don) A. DC.	+	+	C	
Payena maingayi C.B. Clarke		+		4
Payena obscura Burck	+	+	W	
Pouteria maingayi (C.B. Clarke) Baehni	+	+	CNW	
Pouteria malaccensis (C.B. Clarke) Baehni	+	+		
Pouteria obovata (R. Br.) Baehni	+	+		
Sarcosperma paniculatum (King) Stapf & King		+		
SCHISANDRACEAE				
Kadsura scandens Blume		+		1
SCHIZAEACEAE				
Lygodium circinnatum (Burm.*f.*) Sw.			F	1
Lygodium longifolium (Willd.) Sw.	+	+	F	
Lygodium microphyllum (Cav.) R. Br.	+			
Schizaea dichotoma (L.) Sw.	+		FT	
Schizaea digitata (L.) Sw.	+		F	
SCROPHULARIACEAE				
Adenosma javanica (Blume) Koord.	+			
Bacopa monnieri (L.) Wettst.				2
Limnophila laxa Benth.				2
Limnophila sessiliflora (Vahl) Blume	+			
Limnophila villosa Blume	+			
Lindernia crustacea (L.) F. Muell.	+			
Lindernia elata (Benth.) Wettst.	+			
Striga asiatica (L.) Kuntze	+			

Species	R	H	P	S
SELAGINELLACEAE				
Selaginella argentea (Wall. *ex* Hook. & Grev.) Spring	+			
Selaginella intermedia (Blume) Spring	+			
Selaginella willdenowii (Desv.) Baker	+			
SIMAROUBACEAE				
Ailanthus integrifolia Lam.				1
Eurycoma longifolia Jack	+		CW	
SMILACACEAE				
Smilax calophylla Wall. *ex* A. DC.	+	+		
Smilax leucophylla Blume	+	+		
Smilax myosotiflora A. DC.			C	
Smilax setosa Miq.	+	+		
STAPHYLEACEAE				
Turpinia sphaerocarpa Hassk.	+			2
STERCULIACEAE				
Byttneria maingayi Mast.		+		
Commersonia bartramia (L.) Merr.	+	+		
Heritiera borneensis (Merr.) Kosterm.	+	+		
Heritiera elata Ridl.	+	+	NW	
Heritiera javanica (Blume) Kosterm.	+			
Heritiera simplicifolia (Mast.) Kosterm.	+	+	CW	
Melochia corchorifolia L.	+			
Pterocymbium tubulatum (Mast.) Pierre		+		1
Pterospermum javanicum Jungh.		+	C	3
Scaphium linearicarpum (Mast.) Pierre		+		
Scaphium macropodum (Miq.) Beumée *ex* Heyne	+	+	W	
Sterculia coccinea Jack	+	+		
Sterculia cordata Blume	+			2
Sterculia gilva Miq.		+	N	
Sterculia macrophylla Vent.	+		N	
Sterculia parviflora Roxb.	+	+		

Species	R	H	P	S
Sterculia rubiginosa Vent.	+	+	N	
STYRACACEAE				
Styrax benzoin Dryand.	+	+		
SYMPLOCACEAE				
Symplocos adenophylla Wall. *ex* G. Don	+			
Symplocos barringtoniifolia Brand		+	N	
Symplocos fasciculata Zoll.	+	+		
Symplocos odoratissima (Blume) Choisy & Zoll.		+		
Symplocos rubiginosa Wall. *ex* DC.	+	+		
TACCACEAE				
Tacca integrifolia Ker Gawl.	+	+	N	
THEACEAE				
Adinandra acuminata Korth.		+	W	
Adinandra dumosa Jack	+	+	CW	
Adinandra integerrima T. Anderson *ex* Dyer		+		
Eurya acuminata DC.	+			
Gordonia multinervis King	+		W	
Gordonia penangensis Ridl.		+		
Gordonia singaporiana Wall. *ex* Ridl.	+		CW	
Pyrenaria acuminata Planch.	+	+		
Ternstroemia bancana Miq.		+	W	
Ternstroemia penangiana Choisy	+	+		
THELYPTERIDACEAE				
Christella dentata (Forssk.) Brownsey & Jermy	+			
Christella parasitica (L.) Lév.	+			
Cyclosorus interruptus (Willd.) H. Itô	+			
Mesophlebion chylamydophorum (Rosenst. *ex* C. Chr.) Holttum			N	
Mesophlebion motleyanum (Hook.) Holttum	+			
Pronephrium triphyllum (Sw.) Holttum	+			
Sphaerostephanos heterocarpus (Blume) Holttum			N	1

Species	R	H	P	S
THYMELAEACEAE				
Aquilaria hirta Ridl.			C	
Aquilaria malaccensis Lam.	+	+	CNW	
Aquilaria microcarpa Baill.		+		
Enkleia malaccensis Griff.	+	+		
Gonystylus confusus Airy Shaw	+	+	N	
Gonystylus maingayi Hook.*f.*	+	+	C	
Linostoma pauciflorum Griff.		+		
TILIACEAE				
Grewia laevigata Vahl	+	+	N	
Microcos latifolia Burret	+	+	CNW	
Microcos globulifera (Mast.) Burret		+		
Microcos hirsuta (Korth.) Burret		+		
Pentace triptera Mast.	+	+	CNW	
TRIGONIACEAE				
Trigoniastrum hypoleucum Miq.		+		
TRIURIDACEAE				
Sciaphila maculata Miers		+		
Sciaphila tenella Blume		+		
ULMACEAE				
Gironniera hirta Ridl.				1
Gironniera nervosa Planch.	+	+	CW	
Gironniera parvifolia Planch.	+	+	CNW	
Gironniera subaequalis Planch.	+	+		
Trema cannabina Lour.	+	+		
Trema tomentosa (Roxb.) Hara	+	+		
UMBELLIFERAE				
Centella asiatica (L.) Urb.	+			
VERBENACEAE				
Callicarpa longifolia Lam.	+			

Species	R	H	P	S
Clerodendrum deflexum Wall.	+		N	
Clerodendrum laevifolium Blume	+		C	
Clerodendrum villosum Blume	+		N	
Teijsmanniodendron coriaceum (C.B. Clarke) Kosterm.	+		W	
Teijsmanniodendron holophyllum (Baker) Kosterm.	+			
Vitex gamosepala Griff.				4
Vitex pinnata L.	+			2
Vitex vestita Wall. *ex* Schau.	+			2
VIOLACEAE				
Rinorea anguifera (Lour.) Kuntze		+		
VISCACEAE				
Viscum articulatum Burm.*f.*		+		
Viscum ovalifolium Wall. *ex* DC.	+	+		
VITACEAE				
Ampelocissus cinnamomea (Wall.) Planch.				2
Ampelocissus elegans (Kurz) Gagnep.	+	+		
Ampelocissus floccosa (Ridl.) Galet		+		1
Ampelocissus gracilis (Wall.) Planch.	+	+		
Ampelocissus polystachya (Wall.) Planch.		+		
Cayratia mollissima (Wall.) Gagnep.	+	+	N	
Cayratia novemfolia (Wall. *ex* Lawson) Burkill	+	+		
Cissus hastata Miq.	+	+		
Cissus nodosa Blume		+		3
Cissus repens Lam.	+			
Cissus rostrata (Miq.) Planch.				2
Nothocissus spicifera (Griff.) Latiff		+		
Pterisanthes eriopoda (Miq.) Planch.		+		
Pterisanthes polita (Miq.) Lawson	+	+		
Tetrastigma lawsoni (King) Burkill *ex* A.W. Hill				2
Tetrastigma leucostaphylum (Dennst.) Alston *ex* Mabb.		+		
VITTARIACEAE				
Vittaria elongata Sw.				1

Species	R	H	P	S
Vittaria ensiformis Sw.	+		N	
WOODSIACEAE				
Diplazium crenatoserratum (Blume) T. Moore		+		
XYRIDACEAE				
Xyris pauciflora Willd.		+		
ZINGIBERACEAE				
Alpinia conchigera Griff.				1
Amomum hastilabium Ridl.		+	N	
Amomum xanthophlebium Baker	+	+	N	
Elettariopsis curtisii Baker		+		3
Etlingera punicea (Roxb.) R.M.Sm.		+		
Globba leucantha Miq.	+	+	T	
Hornstedtia leonurus (J. König) Retz.	+	+	N	
Hornstedtia scyphifera (J. König) Steud.	+	+	N	
Plagiostachys lateralis Ridl.		+		
Plagiostachys mucida Holttum		+		
Scaphochlamys tenuis Holttum		+		
Zingiber griffithii Baker	+			
Zingiber puberulum Ridl.	+	+		

Appendix 2. Exotic vascular plant species in the Nature Reserves.

(**R** – records from field collections, published data from NRS, and published data during the period 1991–1997 from the "Additions to the Flora of Singapore" and "The Angiosperm Flora of Singapore" series published in the *Gardens' Bulletin Singapore* **44–49**.
H – herbarium specimens records in SING.
P – publication records denoted as follows: C–Corlett (1990, 1991); F–Wee (1983, 1984); N–Corner (1978); T–Chua *et al.* (1996), Tan *et al.* (1995), Tan (1995, 1997); W–Wong (1987).
S – unverified records denoted as follows: 1–observations from NParks staff and NRS unpublished checklists, 2–unpublished checklist of BTNR flora (Corlett, late 80s), 2–collections from the Centre for Natural Product Research (CNPR) project and 4–collections from the CTFS project.)

Species	R	H	P	S
Acacia auriculiformis A. Cunn. *ex* Benth.				1
Acacia mangium Willd.				1
Adiantum latifolium Lam.				1
Ageratum conyzoides L.	+			
Alocasia macrorrhizos (L.) G. Don	+			
Alpinia galanga (L.) Sw.	+			
Aniseia martinicensis (Jacq.) Choisy	+			
Antiaris toxicaria Lesch.				2
Areca catechu L.	+			
Artocarpus heterophyllus Lam.	+	+		
Artocarpus integer (Thunb.) Merr.	+	+		
Asclepias curassavica L.		+		
Asystasia gangetica (L.) T. Anderson subsp. *micrantha* (Nees) Ensermu	+			
Axonopus compressus (Swartz) P. Beauv.				1
Bambusa ?tulda Roxb.	+		T	
Bauhinia ferruginea Roxb.				1
Callerya atropurpurea (Wall.) Schot	+			
Canna indica L.	+			
Cecropia peltata L.	+			
Centrosema plumieri (Turp. *ex* Pers.) Benth.				1
Centrosema pubescens Benth.	+			
Chamaecrista mimosoides (L.) Greene	+	+		
Chloris barbata Sw.				1

Species	R	H	P	S
Cleome aculeata L.		+		
Cleome rutidosperma DC.	+	+		
Clerodendrum paniculatum L.	+			
Clidemia hirta (L.) D. Don	+			
Clitorea laurifolia Poir.	+			
Cocos nucifera L.	+			
Complaya trilobata (L.) Strother				3
Cordia cylindristachya (Ruiz & Pav.) Roem. & Schult.	+			
Costus lucanusianus J. Braun & K. Schum.	+			
Crassocephalum crepidioides (Benth.) S. Moore	+	+		
Dendrocalamus asper (Roem. & Schult.) Baker *ex* Heyne	+		T	
Diodia ocymifolia (Willd. *ex* Roem. & Schult.) Bremek.	+			
Dioscorea hispida Dennst.				2
Dioscorea sansibarensis Pax	+			
Dracaena fragrans (L.) Ker Gawl.	+			
Erechtites hieraciifolia (L.) Raf. *ex* DC.	+			
Etlingera elatior (Jack) R.M. Sm.				3
Ficus benjamina L.				1
Ficus religiosa L.				1
Garcinia mangostana L.	+	+		
Gymnopetalum integrifolium (Roxb.) Kurz				3
Heliconia bihai L.	+			
Heliconia psittacorum L.*f.*	+			
Hevea brasiliensis (Willd. *ex* A. Juss.) Müll. Arg.	+			
Hymenaea courbaril L.	+			
Hyptis brevipes Poit.	+			
Hyptis capitata Jacq.	+			
Indigofera hirsuta L.	+			
Kyllinga polyphylla Willd. *ex* Kunth		+		
Lansium domesticum Corrêa	+			
Lantana camara L.	+			
Leucaena leucocephala (Lam.) de Wit				1
Limnocharis flava (L.) Buchenau	+			
Mangifera indica L.	+			
Manihot esculenta Crantz				1
Manihot glaziovii Müll. Arg.	+			

Species	R	H	P	S
Mikania micrantha Kunth	+			
Mimosa bimucronata (DC.) Kuntze		+		
Mimosa pigra L.	+			
Mimosa pudica L.				1
Momordica charantia L.	+	+		
Morinda citrifolia L.	+			
Oxalis barrelieri L.	+			
Panicum maximum Jacq.				1
Paraserianthes falcataria (L.) I.C. Nielsen		+		1
Passiflora foetida L.	+			
Passiflora laurifolia L.	+			
Passiflora suberosa L.	+			
Pennisetum purpureum Schumach.				1
Peperomia pellucida (L.) Kunth				1
Persicaria chinensis (L.) H. Gross	+			
Persicaria orientalis (L.) Spach	+			
Phyllanthus amarus Schum. & Thonn.				1
Physalis minima L.				1
Pilea microphylla (L.) Liebm.				1
Pityrogramma calomelanos (L.) Link				1
Polygala paniculata L.	+			
Porophyllum ruderale (Jacq.) Cass.				1
Portulaca oleracea L.				1
Psidium guajava L.	+			
Quisqualis indica L.		+		
Ruellia tuberosa L.	+			
Salvinia molesta D.S. Mitchell	+			
Saraca cauliflora Baker	+			
Scoparia dulcis L.				1
Senna alata (L.) Roxb.	+			
Senna siamea (Lam.) Irwin & Barneby	+			
Sida cordifolia L.	+			
Solanum torvum Sw.	+			
Spathodea campanulata P. Beauv.	+			
Stachytarpheta indica (L.) Vahl	+			
Stachytarpheta jamaicensis (L.) Vahl				3

Species	**R**	**H**	**P**	**S**
Struchium sparganophorum Kuntze	+			
Synedrella nodiflora (L.) Gaertn.	+			
Syngonium podophyllum Schott	+			
Thunbergia alata Boj. *ex* Sims	+			
Thunbergia fragrans Roxb.				1
Thunbergia grandiflora (Roxb. *ex* Rottl.) Roxb.	+			
Thysanolaena latifolia (Roxb. *ex* Hornem.) Honda	+	+		
Tridax procumbens L.				1
Trimezia martinicensis (Jacq.) Herbert	+			
Typha angustifolia L.				1
Typhonium trilobatum (L.) Schott				1
Uncaria gambir (W. Hunt.) Roxb.	+	+		
Wikstroemia ridleyi Gamble	+	+		
Zingiber zerumbet (L.) Sm.		+		

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Bird Biodiversity in the Nature Reserves of Singapore

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Abstract

Forest clearance and associated disturbance since 1819 are chiefly responsible for the loss of 70 species from the forest habitat in Singapore. Of the remaining 207 species, 127 are resident of which only 26 are forest dependent. The rest include 72 migrants and 8 non-breeding visitors. A comprehensive survey of the central forests, the last of the terrestrial forests in Singapore, was conducted by members of the Nature Society (Singapore) Bird Group between July 1993 and June 1997, and increased the known species total for the area from 171 in 1989 to 207 by 1997. The 35 additions to the Nature Reserves list included one new to Singapore, Velvet-fronted Nuthatch, and rediscoveries of White-bellied Woodpecker, the first since 1988, Barred Eagle-owl, since 1925 and Yellow-eared Spiderhunter, since 1920. Of 19 key species, 14 were recorded during the survey of which four - Drongo Cuckoo, Blue-rumped Parrot, Blue-crowned Hanging Parrot and Chestnut-winged Babbler - were found to be widespread within the Central Catchment Nature Reserve. Four areas found to be of importance because of high species diversity and concentration of key species were the MacRitchie peninsula, the Mandai Track 15 peninsula, Nee Soon Swamp Forest and the hill primary forest at Bukit Timah Nature Reserve. Conservation and protection of these areas and the control of poaching and illegal introduction of alien birds are the keys to the preservation of the current forest bird diversity and the prevention of further extinction.

Introduction

The central forests consist of two nature reserves in the centre of Singapore: the 2,675 ha Central Catchment Nature Reserve and the recently enlarged 164 ha Bukit Timah Nature Reserve (National Parks Board, *pers. comm.*). These reserves constitute the last remnant of a rainforest habitat that once covered the island and are important as last refuges for many resident bird species. This shrinkage and associated disturbance, which began with the arrival of Stamford Raffles in 1819, resulted in the extinction of 70 resident species that included entire families, such as partridges, hornbills, trogons and broadbills (Lim, 1992, 1997). Other families, normally well represented in the forest habitats of the Sunda region, became very much reduced. These included bulbuls and babblers, with some reduced to just one representative species, e.g., barbets and malkohas (Lim, 1992, 1997).

History

The study of birds in Singapore began with Raffles who collected birds for the British Museum (Lim, 1997). Raffles was followed by Alfred Russel Wallace who collected in Singapore between 1854 and 1862, A.O. Hume (1879-1880), H.R. Kelham (1881—1882) and H.N. Ridley (1898—1901). There followed a lull after which the collecting tradition continued with the arrival of erstwhile curators of the Raffles Museum, F.N. Chasen in the 1920s and 1930s and C.A. Gibson-Hill in the 1940s (Bucknill & Chasen, 1927; Gibson-Hill, 1950). Gibson-Hill and his contemporary, R.J. Spittle, made the first life history studies of birds in Singapore during their World War II internment and were succeeded in 1968 by P. Ward who conducted the first avifaunal studies. However, it was not until the arrival of C.J. Hails in 1983 that the first systematic study of forest birds was carried out. His findings were published in 1987 (Hails & Jarvis, 1987; Hails, 1992). There were no subsequent studies until the National Parks Board's sponsored bird survey which began in 1993 with the participation of volunteers from the Nature Society (Singapore).

Survey Objectives

The Nature Society (Singapore) Bird Group commenced a study of the central forests in July 1993 at the invitation of the National Parks Board (NParks). The field survey took some 48 months to complete and members expended over 1,500 observer-hours during the study. The survey was done in four stages as follows:

MacRitchie Catchment (MC)	: July 1993 - June 1994
Seletar Catchment (SC)	: July 1994 - June 1995
Peirce Catchment (PC)	: July 1995 - June 1996
Bukit Timah (BT)	: July 1996 - June 1997

The objectives of the survey were:

1. to determine the status, diversity, density and population of birds in the Nature Reserves,
2. to map the occurrence of key species (nationally threatened forest dependent species),
3. to recommend methods of maintaining/improving current bird diversity, and
4. to identify areas of high bird diversity.

Materials and Methods

To facilitate a uniform and thorough coverage, the central forests were divided into four parts, each taking one year to complete. In turn, each part was further divided into five smaller sectors (Figure 1), each being supervised by an experienced birdwatcher with the aid of 1—5 assistants.

The methods employed were as follows:

Line transect counts

Line transects were selected from existing trails within each area and designed to be representative of the vegetation type of each sector. The transects varied in length from 0.8 km to 2.3 km.

Two types of transect counts were used: diurnal and nocturnal. Diurnal transect counts were carried out monthly, commencing at 0730 hours and ending at approximately 0830 to 0930 hours, depending on the length of each transect and bird activity. Nocturnal transect counts were also made at less frequent intervals commencing at 1930 hours and ending at approximately 2030 to 2130 hours.

Birds seen or heard during the transect counts were recorded using the 25-metre belt method and an estimation of the population and density derived using the methods recommended by Bibby *et al.* (1992).

The formula used to calculate species density is $D = Nk/L$

where D = density
N = total number of birds counted
k = unknown constant = [1-SQR(1-p)]/W
[p=N1/N where N1 is the total number of birds counted in the inner belt; W = belt width (m)]
L = length of transect (m)

This formula is based on the assumption that all birds occurring within the transect route are counted and that detectability (the k factor) decreases linearly with distance.

Area counts

Line transects are by design confined to a particular route and time. In order that bird diversity and distribution of each area be properly recorded, additional area counts were conducted by the area leaders either before or

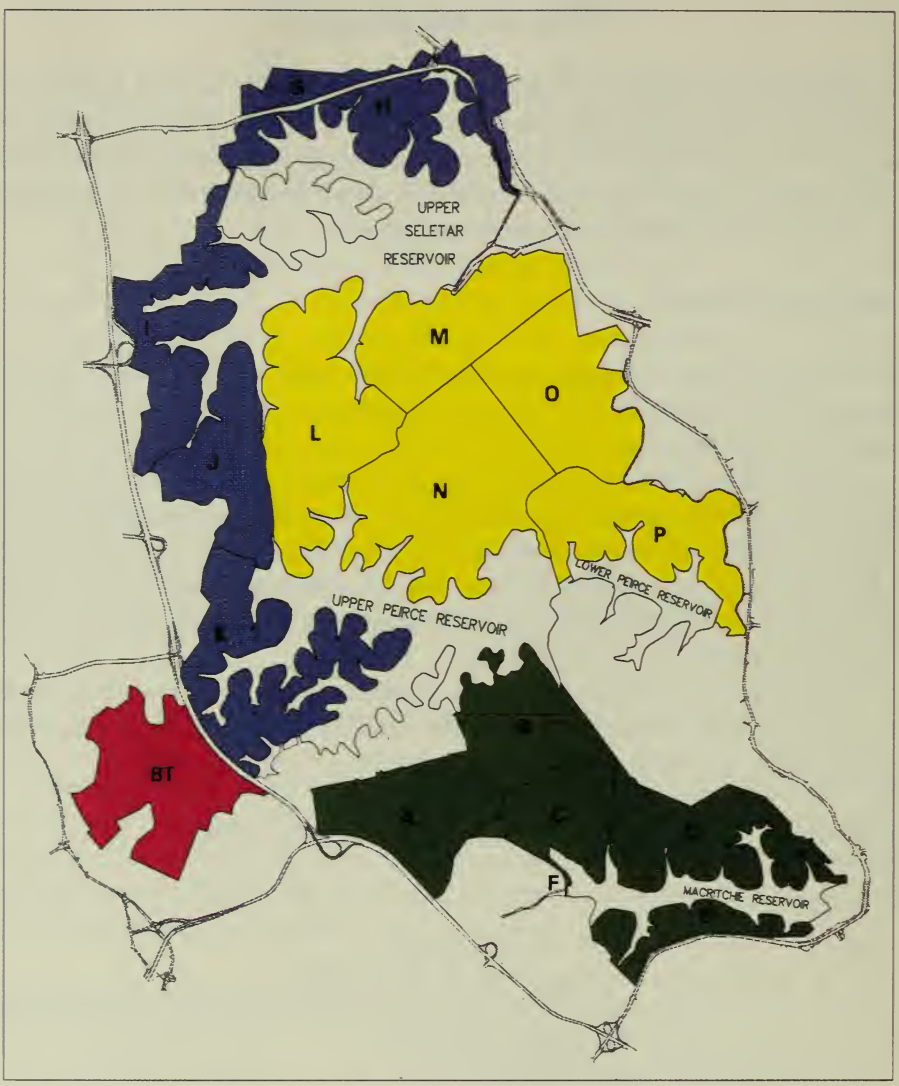

Figure 1. Map showing sectors surveyed in the Nature Reserves.

after line transect counts or on a separate date. Data so obtained were recorded in designated field survey forms and submitted.

Mapping

Mapping of the ranges of key species was conducted for those recorded in transect and area counts on an area-by-area basis. The aim of this mapping study was to determine the occurrence and distribution of key species in each area so that these could be transferred to the NParks' Geographic Information System for future threatened species management and conservation purposes.

Bird ringing

Bird ringing using mist nets and rings belonging to NParks was carried out in order to study the movement and longevity of resident birds and the migration patterns of migrants. Nets were set up along existing trails in the early morning (by 0600 hours) and taken down at noon.

Birds caught in the net were quickly ringed, measured, photographed and released near the site where they were caught.

Results

Annotated checklist of selected species

The following is an annotated checklist of species that are nationally threatened, forest dependent (stenotopic) or key species.

White-bellied Woodpecker (*Dryocopus javensis*)
Large wood-boring insectivore, the only extant stenotopic picid, nationally threatened. Frequents canopy and mid-storey, particularly dead trees. Confined to the MacRitchie Catchment and Bukit Timah Nature Reserve. No more than 2 individuals seen since 1993.

Red-crowned Barbet (*Megalaima rafflesii*)
Large frugivore, the only extant stenotopic barbet, nationally near-threatened. Frequents canopy and upper storey. Occurs only in the Central Catchment and Bukit Timah Nature Reserves. Breeding recorded.

Blue-eared Kingfisher (*Alcedo meninting*)
Small piscivorous kingfisher restricted to forest streams; nationally

threatened. Confined to the Central Catchment Nature Reserve with regular sightings in the MacRitchie area. Breeding recorded in 1997.

Drongo Cuckoo (*Surniculus lugubris*)
Small insectivore favouring the canopy; nationally threatened. Occurs widely throughout Central Catchment and Bukit Timah Nature Reserves. Breeding recorded. Numbers are augmented by winter visitors between October and March.

Chestnut-bellied Malkoha (*Phaenicophaeus sumatranus*)
Large insectivore frequenting all levels from lower storey to canopy, the only extant malkoha; nationally near-threatened. Occurs in both reserves. Breeding recorded.

Blue-rumped Parrot (*Psittinus cyanurus*)
Small frugivore frequenting canopy; nationally threatened. Occurs in both reserves. Breeding not confirmed.

Blue-crowned Hanging Parrot (*Loriculus galgulus*)
Very small frugivore of the canopy; nationally threatened. Occurs in both reserves. Breeding not confirmed.

Glossy Swiftlet (*Collocalia esculenta*)
Very small aerial insectivore of the airspace above forests. Confined to the summit of Bukit Timah. Not recorded since 1990. Breeding not confirmed. Not recorded during the survey.

Brown Hawk-owl (*Ninox scutulata*)
Small insectivore/carnivore; nocturnal; forest stenotopic; common. Frequents the understorey. Occurs throughout the nature reserves. Breeding recorded.

Malaysian Eared-nightjar (*Eurostopodus temminckii*)
Medium-sized aerial insectivore; crepuscular; forest stenotopic; nationally threatened. Feeds over forest canopy and edges. Confined to Central Catchment. Breeding not confirmed.

Crested Serpent-eagle (*Spilornis cheela*)
Large raptor of reptiles and amphibians; forest stenotopic; nationally threatened. Feeds over canopy. Confined to Central Catchment Nature Reserve. Breeding recorded.

Asian Fairy-bluebird (*Irena puella*)
Small frugivore of forest canopy; forest stenotopic; common. Occurs in both reserves. Breeding recorded.

Greater Green Leafbird (*Chloropsis sonnerati*)
Small frugivore of canopy; forest stenotopic; nationally threatened. Occurs in both reserves. Breeding not confirmed.

Lesser Green Leafbird (*Chloropsis cyanopogon*)
Small frugivore of canopy; forest stenotopic; nationally threatened. Occurs in both reserves. Breeding not confirmed.

Lesser Cuckoo-shrike (*Coracina fimbriata*)
Small insectivore of canopy and upper storey; forest stenotopic; nationally threatened. Confined to Bukit Timah Nature Reserve. Not recorded during survey. Breeding not confirmed.

Scarlet Minivet (*Pericrocotus flammeus*)
Small insectivore of canopy; forest stenotopic; nationally threatened. Confined to Bukit Timah Nature Reserve. Breeding recorded.

Black-headed Bulbul (*Pycnonotus atriceps*)
Small frugivore of upper storey; forest stenotopic; nationally threatend. Confined to Central Catchment Nature Reserve. Breeding not confirmed.

Cream-vented Bulbul (*Pycnonotus simplex*)
Small frugivore of mid and lower storeys; forest stenotopic; nationally near-threatened. Occurs in both reserves. Breeding recorded.

Red-eyed Bulbul (*Pycnonotus brunneus*)
Small frugivore of mid and lower storeys; forest stenotopic; nationally threatened. Occurs in both reserves. Breeding recorded.

Buff-vented Bulbul (*Iole olivacea*)
Small frugivore of middle and lower storeys; forest stenotopic; nationally threatened. Confined to Bukit Timah Nature Reserve. Not recorded during the survey. Breeding not confirmed.

Short-tailed Babbler (*Malacocincla malaccensis*)
Small insectivore of forest floor and understorey; forest stenotopic; common. Occurs in both reserves. Breeding recorded.

Moustached Babbler (*Malacopteron magnirostre*)
Small insectivore of understorey; forest stenotopic; nationally threatened. Confined to Central Catchment Nature Reserve. Breeding recorded.

Chestnut-winged Babbler (*Stachyris erythroptera*)
Small insectivore of understorey (especially, resam *Dicranopteris* spp.) frequently seen with Striped Tit-babbler; forest stenotopic; nationally threatened. Occurs in both reserves but rare in Bukit Timah Nature Reserve. Breeding recorded.

Yellow-vented Flowerpecker (*Dicaeum chrysorrheum*)
Very small frugivore/insectivore of understorey to canopy; forest stenotopic; nationally threatened. Occurs in both reserves but not recorded during the survey. Breeding recorded.

Little Spiderhunter (*Arachnothera longirostris*)
Small insectivore/nectarivore of understorey; forest stenotopic; uncommon. Occurs in both reserves. Breeding recorded.

Thick-billed Spiderhunter (*Arachnothera crassirostris*)
Small insectivore/nectarivore of canopy; forest stenotopic; nationally threatened. Confined to Central Catchment Nature Reserve. Not recorded since 1989. Breeding not confirmed.

Yellow-eared Spiderhunter (*Arachnothera chrysogenys*)
Small insectivore/nectarivore of canopy; forest stenotopic; nationally threatened. Confined to Central Catchment Nature Reserve. Breeding not confirmed.

The avifauna

As a result of this survey, 207 species of birds are now known to occur in the Nature Reserves (Appendix 1). Although this is only 59% of the national total i.e., 350 (Lim & Gardner, 1997), the Nature Reserves are home to all 26 extant forest specialists, 40 (75%) of the nationally threatened species (Lim, 1992) and 2 globally threatened species (Collar *et al.*, 1994). This is about 75—80% of the species total of lowland forests of similar size, such as Panti Forest Reserve, Johor and Pasoh Forest Reserve in Negri Sembilan, in Peninsular Malaysia (*pers. obs.*). The most important factor for this impoverishment is the loss of 70 resident species, which if added to the total, would be approximately 100%, in terms of number of species one would expect to record in a Peninsular Malaysian forest of similar size. However, one important difference is dominance of generalist

(eurytopic) species, 101 species (about 80%) of the resident species. In a mainland forest, the percentage of eurytopics would be about 25% (*pers. obs.*; Medway & Wells, 1976). Contributing factors are that Singapore is an island and many species are not able to cross the narrow Johor Straits and the history of land clearance, which created opportunities for open country species to invade forest niches left vacant by extirpated forest species.

During the four-year survey, from July 1993 to June 1997, a total of 175 species (85% of the species total), were recorded from both reserves. The Central Catchment Nature Reserve's bird list increased from 155 to 185 species, an increase of 30 species or 19%. Of the grand total, 170 or 92% were recorded during the survey, with 16 species not detected. Of the 17 key species that had been observed in Central Catchment Nature Reserve, 13 (76%) were recorded during the survey (Table 1). Of the 35 nationally threatened species observed in Central Catchment Nature Reserve, 25 (71%) were recorded. The bird list for Bukit Timah Nature Reserve and its extension increased from 117 to 143, an increase of 26 species or 22%. Of these, 114 were found during the survey, with 29 not detected. Of the 13 key species that had been observed in Bukit Timah Nature Reserve, 8 (62%) were recorded during the survey (Table 1). Of the 21 nationally threatened species previously observed in Bukit Timah Nature Reserve, 15 (71%) were recorded.

Table 1. Distribution of key species in the Nature Reserves.
(MC – MacRitchie Catchment, SC – Seletar Catchment, PC – Peirce Catchment, BT – Bukit Timah)

No.	Common Name	MC	SC	PC	BT
1.	White-bellied Woodpecker	*			
2.	Blue-eared Kingfisher	*	*		
3.	Drongo Cuckoo	*	*	*	*
4.	Blue-rumped Parrot	*	*	*	*
5.	Blue-crowned Hanging Parrot	*	*	*	*
6.	Malaysian Eared-nightjar	*	*	*	
7.	Glossy Swiftlet				
8.	Crested Serpent-eagle	*	*		
9.	Greater Green Leafbird	*			*
10.	Lesser Green Leafbird	*		*	*
11.	Lesser Cuckoo-shrike				
12.	Scarlet Minivet				*
13.	Black-headed Bulbul	*	*		
14.	Red-eyed Bulbul	*		*	*
15.	Buff-vented Bulbul				
16.	Moustached Babbler	*			
17.	Chestnut-winged Babbler	*	*	*	*
18.	Yellow-vented Flowerpecker				
19.	Thick-billed Spiderhunter				

Bird status

Of the 207 bird species recorded in the nature reserves, 127 (61%) are residents, 72 (35%) are migrants and 8 (4%) are non-breeding visitors. Of the total of 185 species recorded in the catchment, 120 (65%) are residents, 65 (35%) are migrants with 1 (1%) non-breeding visitor. For Bukit Timah, its 143 species comprised 91 residents (64%), 47 (33%) migrants and 5 (4%) non-breeding visitors.

Key species

Of the 19 key species, all but 5 species were recorded (Table 1). Of these five, the Glossy Swiftlet was last recorded in 1990, Lesser Cuckoo-shrike in 1986, Buff-vented Bulbul in 1991, Yellow-vented Flowerpecker in 1990 and Thick-billed Spiderhunter in 1989. All but the last-named species are confined to Bukit Timah.

Of the 14 key species recorded, only 4 species - Drongo Cuckoo, Blue-rumped Parrot, Blue-crowned Hanging Parrot and Chestnut-winged Babbler - are relatively widespread and occur in all four areas. The remaining 12 species live a precarious existence, especially those which number less than 5 individuals and occur in a single area, e.g., White-bellied Woodpecker (MacRitchie) and Scarlet Minivet (Bukit Timah).

New discoveries

The survey added several species to the list of the Nature Reserves. Noteworthy amongst these were Large Hawk-cuckoo, Oriental Cuckoo, Red-legged Crake and Velvet-fronted Nuthatch. Stunning rediscoveries included White-bellied Woodpecker (first since 1988), Barred Eagle-owl (1925) and Yellow-eared Spiderhunter (1920). Most of the other additions were forest edge, parkland or open country species recorded within reserve boundaries, e.g., Lower Peirce, Bukit Timah extension.

Other findings

The globally threatened Straw-headed Bulbul appears to be invading from the Sembawang area, being recorded in sectors G, I, P, K and the Bukit Timah extension. The Black-headed Bulbul also occurs in both Chestnut Avenue sectors in addition to its known presence in MacRitchie. Another nationally threatened species, Crested Serpent-eagle is present in E, I, M, N and O. The little known Malaysian Eared-nightjar is also recorded in sectors H, I and P in addition to MacRitchie. Yet another locally threatened

species, Little Green-pigeon, has not been recorded in the central forests or anywhere else in Singapore since it was last seen in the Seletar Catchment in 1992.

Breakdown by areas

Based on the survey results, the bird inventory of the four forest areas is given below:

Areas	Species recorded	Key species
MacRitchie Catchment (MC)	121	13
Seletar Catchment (SC)	114	8
Peirce Catchment (PC)	96	7
Bukit Timah (BT)	114	8

Breakdown by sectors

The following is a breakdown of the individual sectors and their species count (with numbers of key species in parenthesis):

A – 49 (2)	G – 45 (1)	M – 48 (4)
B – 68 (9)	H – 46 (4)	N – 56 (3)
C – 62 (5)	I – 66 (4)	O – 62 (4)
D – 65 (8)	J – 56 (2)	P – 55 (3)
E – 52 (2)	K – 58 (2)	BT – 111 (8)
F – 62 (1)	L – 52 (5)	

High diversity - B, I, D, C, O, BT
High key species - B, D, C, I, H, L, M, O, BT.
High diversity and high key species - B, C, D, I, O, BT.

From this simple comparison, it can be seen that areas of high bird diversity as well as high concentration of key species can be defined as follows:

1. The MacRitchie peninsula comprising sectors B, C & D.
2. The Mandai Track 15 peninsula comprising sector I.
3. The Nee Soon Swamp Forest comprising sector O.
4. Bukit Timah Nature Reserve.

Conclusions

The survey has shown that while some forest dependent species are doing well, having both stable numbers and a wide distribution, virtually all key species exhibit signs of decline. The reasons for this decline are not known but are suspected to be related to the long-term effects of isolation, competition and inbreeding.

Three primary core areas, Bukit Timah, the Sime-Shinto-Thomson peninsula in MacRitchie and Nee Soon Swamp Forest in Peirce, and a secondary one in the Mandai Track 15 area in Seletar, have been identified in the survey. The future of forest dependent, in particular key species, lies in the strict protection of these four sites. In addition, there is a need to ensure that bird populations of the three catchments are allowed to mingle to generate a healthy gene pool by linking intervening waterbodies with corridors and also by conserving adjacent sectors as protective buffers.

The biggest threat to forest birds is unviable population levels for key species and isolation for forest dependent species. A secondary threat is forest clearance and disturbance as these factors result in habitat shrinkage, and the introduction of predators (e.g. mammals) and competitors (generalist birds). A third factor is the introduction of alien birds.

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Appendix 1. A Checklist of the Birds of the Nature Reserves of Singapore.

(Status : R – Resident, M – Migrant, V – Non-breeding Visitor, I – Introduced, ? – Status Uncertain.
Abundance Codes : 1 – Rare, 2 – Common, 3 – Abundant
* - Key species. Species which are nationally threatened and forest dependent.
Location : CCNR – Central Catchment Nature Reserve, BTNR – Bukit Timah Nature Reserve.)

Part A : Species which are believed to be genuinely wild birds.

No.	Common Name	Species	Status	Remarks
1.	Blue-breasted Quail	*Coturnix chinensis*	R1	
2.	Lesser Whistling-Duck	*Dendrocygna javanica*	R1	Nationally threatened.
3.	Cotton Pygmy-Goose	*Nettapus coromandelianus*	R1	Nationally threatened.
4.	Barred Buttonquail	*Turnix suscitator*	R1	
5.	Sunda Woodpecker	*Dendrocopus moluccensis*	R2	
6.	Rufous Woodpecker	*Celeus brachyurus*	R2	
7.	White-bellied Woodpecker*	*Dryocopus javensis*	R1	
8.	Banded Woodpecker	*Picus miniaceus*	R3	
9.	Laced Woodpecker	*Picus vittatus*	R2	
10.	Common Flameback	*Dinopium javanense*	R1	
11.	Red-crowned Barbet	*Megalaima rafflesii*	R2	Forest dependent.
12.	Coppersmith Barbet	*Megalaima haemacephala*	R1	
13.	Dollarbird	*Eurystomus orientalis*	R2	
14.	Common Kingfisher	*Alcedo atthis*	M3	
15.	Blue-eared Kingfisher*	*Alcedo meninting*	R1	Confined to CCNR.
16.	Black-backed Kingfisher	*Ceyx erithacus*	M1	
17.	Stock-billed Kingfisher	*Pelargopsis capensis*	R2	
18.	Ruddy Kingfisher	*Halcyon coromanda*	M1	
19.	White-throated Kingfisher	*Halcyon smyrnensis*	R3	
20.	Black-capped Kingfisher	*Halcyon pileata*	M2	
21.	Collared Kingfisher	*Todirhamphus chloris*	R2	
22.	Blue-throated Bee-eater	*Merops viridis*	R3	
23.	Blue-tailed Bee-eater	*Merops philippinus*	M3	
24.	Chestnut-winged Cuckoo	*Clamator coromandus*	M1	
25.	Large Hawk-cuckoo	*Cuculus sparverioides*	M1	
26.	Hodgson's Hawk-cuckoo	*Cuculus fugax*	M1	
27.	Indian Cuckoo	*Cuculus micropterus*	M2	
28.	Oriental Cuckoo	*Cuculus orientalis*	M1	

No.	Common Name	Species	Status	Remarks
29.	Banded Bay Cuckoo	*Cacomantis sonneratii*	R2	
30.	Plaintive Cuckoo	*Cacomantis merulinus*	R2	
31.	Rusty-breasted Cuckoo	*Cacomantis sepulcralis*	R1	Nationally threatened.
32.	Little Bronze-cuckoo	*Chrysococcyx minutillus*	R1	
33.	Violet Cuckoo	*Chrysococcyx xanthorhynchus*	R2	Nationally threatened.
34.	Drongo Cuckoo*	*Surniculus lugubris*	R2	
35.	Asian Koel	*Eudynamys scolopacea*	R1	
36.	Chestnut-bellied Malkoha	*Phaenicophaeus sumatranus*	R2	Forest dependent.
37.	Greater Coucal	*Centropus sinensis*	R2	
38.	Lesser Coucal	*Centropus bengalensis*	R1	
39.	Tanimbar Cockatoo	*Cacatua goffini*	IR1	
40.	Blue-rumped Parrot*	*Psittinus cyanurus*	R1	
41.	Blue-crowned Hanging Parrot*	*Loriculus galgulus*	R1	
42.	Rose-ringed Parakeet	*Psittacula krameri*	IR1	
43.	Red-breasted Parakeet	*Psittacula alexandri*	IR1	
44.	Long-tailed Parakeet	*Psittacula longicauda*	R3	
45.	Glossy Swiftlet*	*Collocalia esculenta*	R1	Confined to BTNR.
46.	Black-nest Swiftlet	*Collocalia maxima*	R3	
47.	Edible-nest Swiftlet	*Collocalia fuciphaga*	R3	
48.	Silver-backed Needletail	*Hirundapus cochinchinensis*	M1	
49.	Brown-backed Needletail	*Hirundapus giganteus*	M1	
50.	Asain Palmswift	*Cypsiurus balasiensis*	R2	
51.	Fork-tailed Swift	*Apus pacificus*	M2	
52.	House Swift	*Apus nipalensis*	R3	
53.	Grey-rumped Treeswift	*Hemiprocne longipennis*	R2	
54.	Oriental Scops-owl	*Otus sunia*	M1	
55.	Collared Scops-owl	*Otus lempiji*	R3	
56.	Barred Eagle-owl	*Ketupa ketupu*	V1	
57.	Buffy Fish-owl	*Ketupa ketupu*	R1	Nationally threatened.
58.	Spotted Wood-owl	*Strix seloputo*	R1	Nationally threatened.
59.	Brown Hawk-owl	*Ninox scutulata*	R3	Forest dependent.
60.	Malaysian Eared-nightjar*	*Eurostopodus temminckii*	R1	Confined to CCNR.
61.	Grey Nightjar	*Caprimulgus indicus*	M1	
62.	Large-tailed Nightjar	*Caprimulgus macrurus*	R3	
63.	Rock Pigeon	*Columba livia*	IR2	
64.	Spotted Dove	*Streptopelia chinensis*	R2	

No.	Common Name	Species	Status	Remarks
65.	Emerald Dove	*Chalcophaps indica*	R2	
66.	Zebra Dove	*Geopelia striata*	R1	
67.	Little Green-pigeon	*Treron olax*	R1	Nationally threatened.
68.	Pink-necked Green-pigeon	*Treron vernans*	R3	
69.	Thick-billed Green-pigeon	*Treron curvirostra*	R2	Nationally threatened.
70.	Jambu Fruit-dove	*Ptilinopus jambu*	V1	
71.	Pied Imperial Pigeon	*Ducula bicolor*	V1	
72.	Red-legged Crake	*Rallina fasciata*	R1	Nationally threatened.
73.	White-breasted Waterhen	*Amaurornis phoenicurus*	R1	
74.	Pintail Snipe	*Gallinago stenura*	M2	
75.	Common Sandpiper	*Tringa hypoleucos*	M3	
76.	Common Greenshank	*Tringa nebularia*	M2	
77.	Pheasant-tailed Jacana	*Hydrophasianus chirurgus*	M1	
78.	Pacific Golden Plover	*Pluvialis fulva*	M1	
79.	Oriental Pratincole	*Glareola maldivarum*	M1	
80.	Little Tern	*Sterna albifrons*	R2	Nationally threatened.
81.	White-winged Tern	*Chlidonias leucopterus*	M2	
82.	Osprey	*Pandion haliaetus*	M2	
83.	Black Baza	*Aviceda leuphotes*	M2	
84.	Oriental Honey-buzzard	*Pernis ptilorhyncus*	M2	
85.	Brahiminy Kite	*Haliastur indus*	R3	
86.	White-bellied Fish-eagle	*Haliaeetus leucogaster*	R3	
87.	Grey-headed Fish-eagle	*Ichthyophaga ichthyaetus*	R2	Nationally threatened.
88.	Crested Serpent-eagle*	*Spilornis cheela*	R1	Confined to CCNR.
89.	Eastern Marsh-harrier	*Circus spilonotus*	M1	
90.	Himalayan Griffon	*Gyps himalayensis*	V1	
91.	Crested Goshawk	*Accipiter trivirgatus*	R1	Nationally threatened.
92.	Chinese Goshawk	*Accipiter soloensis*	M1	
93.	Japanese Sparrowhawk	*Accipiter gularis*	M3	
94.	Besra	*Accipiter virgatus*	V1	
95.	Grey-faced Buzzard	*Butastur indicus*	M1	
96.	Changeable Hawk-eagle	*Spizaetus cirrhatus*	R2	Nationally threatened.
97.	Black-thighed Falconet	*Microhierax fringillarius*	R1	Nationally threatened.
98.	Peregrine Falcon	*Falco peregrinus*	M1	
99.	Purple Heron	*Ardea purpurea*	R2	
100.	Great Egret	*Casmerodius albus*	M1	

No.	Common Name	Species	Status	Remarks
101.	Cattle Egret	*Bubulcus ibis*	M1	
102.	Chinese Pond-heron	*Ardeola bacchus*	M1	
103.	Striated Heron	*Butorides striatus*	R3	
104.	Black-crowned Night-heron	*Nycticorax nycticorax*	R1	Nationally threatened.
105.	Malayan Night-heron	*Gorsachius melanolophus*	M1	
106.	Yellow Bittern	*Ixobrychus sinensis*	M1	
107.	Schrenck's Bittern	*Ixobrychus eurhythmus*	M1	
108.	Cinnamon Bittern	*Ixobrychus cinnamomeus*	R1	
109.	Black Bittern	*Ixobrychus flavicollis*	M1	
110.	Hooded Pitta	*Pitta sordida*	M1	
111.	Blue-winged Pitta	*Pitta moluccensis*	M1	
112.	Golden-bellied Gerygone	*Gerygone sulphurea*	R1	
113.	Asian Fairy-bluebird	*Irena puella*	R3	Forest dependent.
114.	Greater Green Leafbird*	*Chloropsis sonnerati*	R1	
115.	Lesser Green Leafbird*	*Chloropsis cyanopogon*	R2	
116.	Blue-winged Leafbird	*Chloropsis cochinchinensis*	R3	
117.	Tiger Shrike	*Lanius tigrinus*	M3	
118.	Brown Shrike	*Lanius cristatus*	M2	
119.	House Crow	*Corvus splendens*	R1	
120.	Large-billed Crow	*Corvus macrorhynchos*	R3	
121.	Black-naped Oriole	*Oriolus chinensis*	R3	
122.	Lesser Cuckoo-shrike*	*Coracina fimbriata*	R1	Confined to BTNR.
123.	Pied Triller	*Lalage nigra*	R2	
124.	Ashy Minivet	*Pericrocotus divaricatus*	M2	
125.	Scarlet Minivet*	*Pericrocotus flammeus*	R1	
126.	Pied Fantail	*Rhipidura javanica*	R1	
127.	Ashy Drongo	*Dicrurus leucophaeus*	M1	
128.	Crow-billed Drongo	*Dicrurus annectans*	M2	
129.	Greater Racket-tailed Drongo	*Dicrurus paradiseus*	R3	
130.	Asian Paradise-flycatcher	*Terpsiphone paradisi*	M2	
131.	Japanese Paradise-flycatcher	*Terpsiphone atrocaudata*	M1	
132.	Common Iora	*Aegithina tiphia*	R2	
133.	White-throated Rock-thrush	*Monticola gularis*	M1	
134.	Blue Rock-thrush	*Monticola solitarius*	M1	
135.	Orange-headed Thrush	*Zoothera citrina*	M1	
136.	Siberian Thrush	*Zoothera siberica*	M1	

No.	Common Name	Species	Status	Remarks
137.	Eyebrowed Thrush	*Turdus obscurus*	M1	
138.	Brown-chested Jungle-flycatcher	*Rhinomyias brunneata*	M1	Globally threatened.
139.	Dark-sided Flycatcher	*Muscicapa sibirica*	M2	
140.	Asian Brown Flycatcher	*Muscicapa dauurica*	M3	
141.	Ferruginous Flycatcher	*Muscicapa ferruginea*	M1	
142.	Yellow-rumped Flycatcher	*Ficedula zanthopygia*	M3	
143.	Narcissus Flycatcher	*Ficedula narcissina*	M1	
144.	Mugimaki Flycatcher	*Ficedula mugimaki*	M1	
145.	Blue-and-white Flycatcher	*Cyanoptila cyanomelana*	M1	
146.	Siberian Blue Robin	*Luscinia cyanea*	M3	
147.	Oriental Magpie-robin	*Copsychus saularis*	R1	Nationally threatened.
148.	White-rumped Shama	*Copsychus malabaricus*	R1	Nationally threatened.
149.	Asian Glossy Starling	*Aplonis panayensis*	R3	
150.	Purple-backed Starling	*Sturnus sturninus*	M3	
151.	Common Myna	*Acridotheres tristis*	R2	
152.	Javan Myna	*Acridotheres javanicus*	R3	
153.	Hill Myna	*Gracula religiosa*	R3	
154.	Velvet-fronted Nuthatch	*Sitta frontalis*	V1	
155.	Barn Swallow	*Hirundo rustica*	M3	
156.	Pacific Swallow	*Hirundo tahitica*	R3	
157.	Red-rumped Swallow	*Hirundo daurica*	M2	
158.	Asian House-martin	*Delichon dasypus*	M1	
159.	Straw-headed Bulbul	*Pycnonotus zeylanicus*	R2	Globally/nationally threatened.
160.	Black-headed Bulbul*	*Pycnonotus atriceps*	R1	Confined to CCNR.
161.	Black-crested Bulbul	*Pycnonotus melanicterus*	IR2	
162.	Red-whiskered Bulbul	*Pycnonotus jocosus*	IR2	
163.	Yellow-vented Bulbul	*Pycnonotus goiavier*	R3	
164.	Olive-winged Bulbul	*Pycnonotus plumosus*	R3	
165.	Cream-vented Bulbul	*Pycnonotus simplex*	R2	Forest dependent.
166.	Red-eyed Bulbul*	*Pycnonotus brunneus*	R2	
167.	Buff-vented Bulbul*	*Iole olivacea*	R1	Confined to BTNR.
168.	Streaked Bulbul	*Ixos malaccensis*	V1	
169.	Ashy Bulbul	*Hemixos flavala*	M1	
170.	Yellow-bellied Prinia	*Prinia flaviventris*	R1	
171.	Pallas's Warbler	*Locustella certhiola*	M1	

No.	Common Name	Species	Status	Remarks
172.	Common Tailorbird	*Orthotomus sutorius*	R1	
173.	Dark-necked Tailorbird	*Orthotomus atrogularis*	R3	
174.	Rufous-tailed Tailorbird	*Orthotomus sericeus*	R2	
175.	Inornate Warbler	*Phylloscopus inornatus*	M1	
176.	Arctic Warbler	*Phylloscopus borealis*	M3	
177.	Eastern Crowned-warbler	*Phylloscopus coronatus*	M2	
178.	White-crested Laughingthrush	*Garrulax canorus*	IR1	
179.	Hwamei	*Garrulax canorus*	IR2	
180.	White-chested Babbler	*Trichastoma rostratum*	R1	Nationally threatened.
181.	Abbott's Babbler	*Malacocincla abbotti*	R2	
182.	Short-tailed Babbler	*Malacocincla malaccensis*	R3	Forest dependent.
183.	Moustached Babbler*	*Malacopteron magnirostre*	R1	Confined to CCNR.
184.	Chestnut-winged Babbler*	*Stachyris erythroptera*	R2	
185.	Striped Tit-babbler	*Macronous gularis*	R3	
186.	Thick-billed Flowerpecker	*Dicaeum agile*	V1	
187.	Yellow-vented Flowerpecker*	*Dicaeum chrysorrheum*	R1	
188.	Orange-bellied Flowerpecker	*Dicaeum trigonostigma*	R3	
189.	Scarlet-backed Flowerpecker	*Dicaeum cruentatum*	R2	
190.	Plain-throated Sunbird	*Anthreptes malacensis*	R2	
191.	Purple-throated Sunbird	*Neactarinia sperata*	R2	
192.	Olive-backed Sunbird	*Nectarinia jugularis*	R1	
193.	Crimson Sunbird	*Aethopyga siparaja*	R3	
194.	Little Spiderhunter	*Arachnothera longirostris*	R3	Forest dependent.
195.	Thick-billed Spiderhunter*	*Arachnothera crassirostris*	R1	Confined to CCNR.
196.	Yellow-eared Spiderhunter	*Arachnothera chrysogenys*	R1	Nationally threatened.
197.	Eurasian Tree-sparrow	*Passer montanus*	R1	
198.	Forest Wagtail	*Dendronanthus indicus*	M2	
199.	Yellow Wagtail	*Motcilla flava*	M1	
200.	Grey Wagtail	*Motacilla cinerea*	M1	
201.	Paddyfield Pipit	*Anthus rufulus*	R2	
202.	Baya Weaver	*Ploceus philippinus*	R1	
203.	White-rumped Munia	*Lonchura striata*	R1	Nationally threatened.
204.	Javan Munia	*Lonchura leucogastroides*	IR1	
205.	Scaly-breasted Munia	*Lonchura punctulata*	R2	
206.	Black-headed Munia	*Lonchura malacca*	R1	
207.	White-headed Munia	*Lonchura maja*	R2	

Part B: Species that are suspected to be escapees.

No.	Common Name
1.	Red Junglefowl
2.	Oriental Pied Hornbill
3.	Black Magpie
4.	Red Lory
5.	Black Hornbill
6.	Sooty-headed Bulbul
7.	Milky Stock
8.	Painted Stock
9.	Great Argus
10.	Australian Pelican
11.	Azure-winged Magpie
12.	Green Wood-hoopoe
13.	Grey Treepie
14.	Silver-eared Mesia
15.	Black-winged Starling

Part C : Species which are of doubtful status. i.e., their origin cannot be ascertained.

No.	Common Name
1.	Grey-headed Canary-flycatcher
2.	Red-bearded Bee-eater
3.	Red-throated Barbet
4.	Mountain Imperial Pigeon
5.	Maroon Woodpecker

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The Diversity and Conservation Status of Fishes in the Nature Reserves of Singapore

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Abstract

An update on the taxonomy and conservation status of the 61 indigenous species of freshwater fishes now known from Singapore is provided. Of these, 26 species (43%) are extinct. Of the 35 extant species, 33 are known in the Nature Reserves and 21 appear to be restricted there. Of the 52 introduced species of fish in Singapore, 17 are present in the Nature Reserves. The conservation status of native fishes in the Nature Reserves is assessed and the survival of highly threatened species discussed. The significance of the Nature Reserves for freshwater fish conservation is highlighted.

Introduction

The freshwater fish fauna of Singapore is among the best studied in the region and has been the subject of many publications (Alfred, 1961, 1966; Johnson, 1973; Munro, 1990; Lim & P.K.L. Ng, 1990; P.K.L. Ng & Lim, 1996). In the first major synopsis of the Singapore ichthyofauna, Alfred (1966) listed a total of 73 native and introduced species from Singapore of which 42 were still extant. Alfred (1968) subsequently listed 35 native species as extant and believed 19 were extinct.

It was 22 years before the next appraisal was made by Lim & P.K.L. Ng (1990) in their guide to the freshwater fishes of Singapore. By then, several developments had taken place with direct implications on local freshwater fish conservation. *Channa gachua*, one of the species presumed extinct by Alfred (1968) was rediscovered (P.K.L. Ng & Lim, 1989), while two others, *Channa melasoma* and *Pseudomystus rugosus* [as *Leiocassis* cf. *siamensis*] were added to the Singapore ichthyofauna (P.K.L. Ng & Lim, 1990; Munro, 1990). P.K.L. Ng & Lim (1996) subsequently reviewed what was known about the freshwater fish fauna of Singapore, listing 104 species of which 59 were regarded as native species, with 23 being extinct.

Over the years, taxonomic revisions of several groups have also shown that some of the old records were misidentifications. From studies by P.K.L. Ng & Kottelat (1994), H.H. Ng & Lim (1995), Tan & P.K.L. Ng (1996) and

Siebert (1997), five species were added to Singapore's known fauna, viz. *Betta tomi* (specimens had been misidentified as *B. pugnax*), *Ompok fumidus* (misidentified as *O. leiacanthus*), *Parakysis longirostris* (misidentified as *P. verrucosus*), *Rasbora paucisqualis* (misidentified as *R. bankanensis*) and *Puntius banksi* (misidentified as *P. binotatus*). Of these, *Betta tomi* and *Ompok fumidus* are now regarded as extinct (P.K.L. Ng & Kottelat, 1994; Tan & P.K.L. Ng, 1996).

A synopsis of the freshwater fish fauna in the Nature Reserves (Central Catchment and Bukit Timah Nature Reserves) of Singapore (Table 1) is provided together with an annotated checklist for native and exotic species, both extant and recently extinct. General localities within the Central Catchment Nature Reserve (CCNR) and the Bukit Timah Nature Reserve (BTNR) where each species is presently known to occur are provided. We also examine how the continued conservation of the remaining forest in the centre of the island (i.e., the Nature Reserves) is necessary for the long-term survival of most of the extant fauna. The emphasis is on species that complete their life cycle in fresh water.

Table 1. Extant indigenous freshwater fish species of Singapore.
(EN = Endangered, CO = Common, UN = Uncommon, FO = Forest waters, OP = Open waters, NSS = Nee Soon Swamp Forest, BTNR = Bukit Timah Nature Reserve, NR = Nature Reserves (excluding NSS and BTNR), OA = Open rural areas, + = present, - = absent)

No.	Species	Status	Habitat	NSS	BTNR	NR	OA
	Family **CYPRINIDAE**						
1.	*Boraras maculatus*	EN	FO	-	-	+	-
2.	*Cyclocheilichthys apogon*	EN	FO	-	-	+	-
3.	*Puntius banksi*	CO	FO	+	+	+	-
4.	*Puntius hexazona*	EN	FO	+	-	-	-
5.	*Puntius lateristriga*	EN	FO	-	+	+	-
6.	*Rasbora einthovenii*	CO	FO	+	+	+	+
7.	*Rasbora elegans*	CO	FO	+	+	+	-
8.	*Rasbora heteromorpha*	EN	FO	+	-	+	-
	Family **BALITORIDAE**						
9.	*Nemacheilus selangoricus*	EN	FO	+	-	-	-
	Family **COBITIDAE**						
10.	*Pangio shelfordii*	EN	FO	+	-	-	-
	Family **SILURIDAE**						
11.	*Silurichthys hasselti*	EN	FO	+	-	-	-

No.	Species	Status	Habitat	NSS	BTNR	NR	OA
	Family **CLARIIDAE**						
12.	*Clarias batrachus*	CO	OP	-	-	+	+
13.	*Clarias teijsmanni*	EN	FO	+	+	+	-
	Family **AKYSIDAE**						
14.	*Parakysis longirostris*	EN	FO	+	-	-	-
	Family **BAGRIDAE**						
15.	*Mystus gulio*	CO	OP	-	-	-	+
16.	*Pseudomystus rugosus*	EN	FO	+	-	-	-
	Family **APLOCHEILIDAE**						
17.	*Aplocheilus panchax*	CO	OP	+	+	+	+
	Family **ADRIANICHTHYIDAE**						
18.	*Oryzias javanicus*	CO	OP	-	-	-	+
	Family **HEMIRAMPHIDAE**						
19.	*Dermogenys pusilla*	CO	OP/FO	+	+	+	+
20.	*Hemirhamphodon pogonognathus*	EN	FO	+	-	+	-
	Family **NANDIDAE**						
21.	*Nandus nebulosus*	EN	FO	-	+	+	-
	Family **GOBIIDAE**						
22.	*Gobiopterus birtwistlei*	CO	OP	-	-	+	+
23.	*Oxyeleotris marmorata*	CO	OP/FO	+	+	+	+
	Family **ANABANTIDAE**						
24.	*Anabas testudineus*	CO	OP/FO	+	+	+	+
	Family **OSPHRONEMIDAE**						
25.	*Betta imbellis*	UN	OP/FO	-	-	+	+
26.	*Betta pugnax*	CO	FO	+	+	+	-
27.	*Luciocephalus pulcher*	EN	FO	+	-	+	-
28.	*Trichogaster trichopterus*	CO	OP	-	+	+	+
29.	*Trichopsis vittata*	CO	OP/FO	+	+	+	+
	Family **CHANNIDAE**						
30.	*Channa gachua*	EN	FO	+	+	+	-
31.	*Channa lucius*	CO	FO	+	+	+	-
32.	*Channa melasoma*	EN	FO	+	-	+	-
33.	*Channa striata*	CO	OP/FO	+	+	+	+
	Family **MASTACEMBELIDAE**						
34.	*Macrognathus maculatus*	EN	FO	+	-	-	-
	Family **SYNBRANCHIDAE**						
35.	*Monopterus albus*	CO	OP/FO	+	+	+	+

Unless otherwise stated, material has been examined of all species found in the Nature Reserves. These are deposited in the Zoological Reference Collection (ZRC) of the Raffles Museum of Biodiversity Research, Department of Biological Sciences, National University of Singapore. Much of the findings came from surveys conducted under the purview of the National Parks Board. However, recent surveys on the fish fauna of the Nature Reserves have not been exhaustive as some streams and reservoir inlets are difficult to access. Measurements are of the standard length (SL) unless otherwise stated. Taxonomic and ecological notes on each species already mentioned in Alfred (1966), Lim & P.K.L. Ng (1990) and P.K.L. Ng & Lim (1996) are not repeated. Systematic classification follows Nelson (1994) with some modifications.

Annotated Checklist

Extant Native Species in the Nature Reserves

Order Cypriniformes

Family Cyprinidae

Boraras maculatus (Duncker)
CCNR: streams and swamps in Sime Road forest and along southern shore of MacRitchie Reservoir.

Cyclocheilichthys apogon (Valenciennes)
CCNR: MacRitchie Reservoir, and streams in Sime Road forest.
The probability of this species having been introduced many years ago cannot be ascertained as it is widely distributed in Southeast Asia.

Puntius banksi Herre
CCNR: common in streams in the Nee Soon Swamp Forest, Lower Peirce forest and Sime Road forest. BTNR: swamp along eastern boundary.

Puntius hexazona Weber & de Beaufort
CCNR: apparently restricted to the Nee Soon Swamp Forest.

Puntius lateristriga (Valenciennes)
CCNR: streams in the Sime Road and Lower Peirce forests. BTNR: swamp along eastern boundary.

Rasbora einthovenii (Bleeker)
CCNR: common in streams throughout area. BTNR: swamp along eastern boundary.

Rasbora elegans Volz
CCNR: common in streams throughout the area. BTNR: swamp along eastern boundary.

Rasbora heteromorpha Duncker
CCNR: streams in the Sime Road forest and Nee Soon Swamp Forest.

Family Balitoridae

Nemacheilus selangoricus Duncker
CCNR: apparently restricted to streams in the Nee Soon Swamp Forest.

Family Cobitidae

Pangio shelfordii (Popta)
CCNR: apparently restricted to streams in the Nee Soon Swamp Forest. The species name is mis-spelt as *sheldfordii* by P.K.L. Ng & Lim (1996: 111).

Order Siluriformes

Family Siluridae

Silurichthys hasseltii Bleeker
CCNR: apparently restricted to streams in the Nee Soon Swamp Forest. The genus *Silurichthys* was recently revised by H.H. Ng & P.K.L. Ng (1998: 302).

Family Bagridae

Pseudomystus rugosus (Regan)
CCNR: known only from streams in the Nee Soon Swamp Forest. Identified as *Pseudomystus* cf. *siamensis* by P.K.L. Ng & Lim, (1996: 112, Fig. 2), the specimens appear to fit the descriptions for *Pseudomystus rugosus* best, but lack black markings on the caudal fin. Conspecific examples are also known from Pulau Bintan, the large Indonesian island off the southeastern coast of Singapore.

Family Akysidae

Parakysis longirostris Ng & Lim
CCNR: apparently confined to streams in the Nee Soon Swamp Forest. This species was recently described from Singapore (type locality) by H.H. Ng & Lim (1995).

Family Clariidae

Clarias batrachus (Linnaeus)
CCNR: drainages along boundary and in exposed areas. BTNR: drainages along boundary.

Clarias teijsmanni Bleeker
CCNR: Nee Soon Swamp Forest.
This species appears to be confined to shaded streams, while *Clarias batrachus* frequents exposed habitats.

Order Cyprinodontiformes

Family Aplocheilidae

Aplocheilus panchax (Hamilton)
CCNR: common in open bodies of water, especially the MacRitchie Reservoir and streams in the adjacent Sime Road forest and Seletar Reservoir Park.

Order Beloniformes

Family Hemiramphidae

Dermogenys pusilla van Hasselt
CCNR: MacRitchie Reservoir and adjacent streams in Sime Road forest. Also in streams in the Upper Seletar Reservoir Park and along Lorong Banir.
The populations in the MacRitchie Reservoir and Sime Road forest are land-locked.

Hemirhamphodon pogonognathus (Bleeker)
CCNR: streams in the Nee Soon Swamp Forest and Sime Road forest.

Order Perciformes

Family Nandidae

Nandus nebulosus (Gray)
CCNR: streams in the Sime Road and Lower Peirce forests. BTNR: swamp along eastern boundary.

Family Gobiidae
The family Eleotrididae in which *Oxyeleotris marmorata* used to belong, has been included in the Gobiidae (see Hoese & Gill, 1993; Lim & Larson, 1994).

Gobiopterus birtwistlei (Herre)
CCNR: Lower Peirce Reservoir.
Although it is mainly found in brackish water of estuarine areas, this species appears to be able to breed under land-locked conditions as in the Tengeh Reservoir in the Western Catchment.

Oxyeleotris marmorata Bleeker
CCNR: common in the Upper Seletar and Lower Peirce Reservoirs, and their adjacent streams.

Family Anabantidae

Anabas testudineus (Bloch)
CCNR: common in streams and swamps.

Family Osphronemidae
The families Belontiidae and Luciocephalidae are presently part of the Osphronemidae (Britz *et al.*, 1995).

Betta imbellis Ladiges
CCNR: streams in the Sime Road forest and along Lorong Banir.

Betta pugnax (Cantor)
CCNR: common in small streams and swamps throughout area. BTNR: swamp along eastern boundary, Jungle Fall Valley.
This is the most common anabantoid in forest areas and is the only fish present in small streams in the interior of the Bukit Timah Nature Reserve.

Luciocephalus pulcher (Gray)
CCNR: appears to be restricted to streams in the Nee Soon Swamp Forest.

Trichogaster trichopterus (Pallas)
CCNR: exposed water bodies.

Trichopsis vittata (Cuvier)
CCNR: common in exposed and weed-choked water bodies. BTNR: swamp along eastern boundary.

Family Channidae

Channa gachua (Hamilton)
CCNR: small streams in the Nee Soon Swamp Forest and the Chestnut Drive area.
The population from the Bukit Timah Nature Reserve (Johnson, 1973: 110 as *Ophicephalus gachua*) has not been seen in recent years.

Channa lucius (Cuvier)
CCNR: streams in the Nee Soon Swamp Forest and Sime Road forest, and Lower Peirce Reservoir. BTNR: swamp along eastern boundary.

Channa melasoma (Bleeker)
CCNR: small streams in the Nee Soon Swamp Forest and Lower Peirce Forest.

Channa striata (Bloch)
CCNR: common in water bodies.

Order Synbranchiformes

Family Synbranchidae

Monopterus albus (Zuiew)
CCNR: in streams and swamps.

Family Mastacembelidae

Macrognathus maculatus (Valenciennes)
CCNR: appears to be restricted to streams in the Nee Soon Swamp Forest and adjacent areas.

Recently Extinct Native Species

Alfred (1966) has already discussed in some detail the freshwater fish species previously known from Singapore (Table 2). Some species, (e.g., *Wallago leerii* and *Tor tambroides*) which were supposed to have occurred in Singapore in the past but are now extinct, and whose presence in Singapore has been debated have been discussed by Johnson (1973) and Lim & P.K.L. Ng (1990). One species which Alfred (1966) listed as extinct has since been refound (*Channa gachua*, fide P.K.L. Ng & Lim, 1989). In addition, *Channa melasoma* and *Pseudomystus rugosus* (P.K.L. Ng & Lim, 1990, 1992, respectively) are new records.

Table 2. Extinct indigenous freshwater fish species.
(FO = Forest waters, OP = Open waters, LRF = large river fauna, + = present, - = absent)

No.	Species	Habitat	LRF
	Family **CYPRINIDAE**		
1.	*Barbodes schwanenfeldii*	FO/OP	+
2.	*Discherodontus halei*	FO	+
3.	*Hampala macrolepidota*	FO	+
4.	*Labiobarbus festivus*	FO	+
5.	*Osteochilus melanopleura*	FO	+
6.	*Osteochilus spilurus*	FO	-
7.	*Oxygaster anomalura*	FO	+
8.	*Puntius dunckeri*	FO	-
9.	*Rasbora cephalotaenia*	FO	-
10.	*Rasbora paucisqualis*	FO/OP	-
11.	*Tor tambroides*	FO	+
	Family **COBITIDAE**		
12.	*Pangio semicincta*	FO	-
	Family **SILURIDAE**		
13.	*Micronema micronema*	FO	+
14.	*Ompok bimaculatus*	FO	+
15.	*Ompok fumidus*	FO	-
16.	*Wallago leerii*	FO	+
	Family **CLARIIDAE**		
17.	*Clarias meladerma*	FO	+
	Family **SISORIIDAE**		
18.	*Glyptothorax fuscus*	FO	+
	Family **BAGRIDAE**		
19.	*Hemibagrus nemurus*	FO	+

No.	Species	Habitat	LRF
	Family **PRISTOLEPIDAE**		
20.	*Pristolepis fasciata*	FO	+
	Family **GOBIIDAE**		
21.	*Pseudogobiopsis oligactis*	OP/FO	-
22.	*Pseudogobiopsis siamensis*	OP/FO	-
	Family **OSPHRONEMIDAE**		
23.	*Belontia hasselti*	FO	-
24.	*Betta tomi*	FO	-
	Family **MASTACEMBELIDAE**		
25.	*Macrognathus aculeatus*	FO	-
26.	*Mastacembelus armatus*	FO	+

P.K.L. Ng *et al.* (1994) subsequently published a selective list of Singapore freshwater fishes which they believed were under threat, listing 18 as extinct and 17 as locally endangered species. Three species, *Rasbora paucisqualis* (as *R. bankanensis*), *Pangio semicincta* and *Glyptothorax fuscus* were listed as being probably extinct as there had been no recent records. All three are relatively common species in southern Malaysia where they are easily found in disturbed areas adjacent to forests. The failure to obtain these species in Singapore for so many years is a good indication that they are no longer extant.

Alfred (1966, 1968) believed that one species originally described from Singapore, *Hemibagrus elongatus*, was extinct. Kottelat *et al.* (1998) believe this species is actually a Chinese and Vietnamese one, and should be excluded from the Singapore faunal list.

Family Cyprinidae

Rasbora paucisqualis Ahl
Since its rediscovery by Alfred (1966: 17 as *Rasbora bankanensis*), it has not been seen again.

Family Cobitidae

Pangio semicincta (Fraser-Brunner)
Earlier identified as *Pangio kuhlii* (Alfred, 1966; P.K.L. Ng & Lim, 1996: 111) under which *P. semicincta* was synonymised (Kottelat & Lim, 1993)

M. Kottelat (*pers. comm.*) now believes *P. kuhlii* is restricted to its type locality in Java. The forms on Sumatra, the Malay Peninsula (and Singapore) and Borneo are *P. semicincta*. This fish has not been encountered since 1966 and we believe that it is locally extinct.

Family Sisoridae

Glyptothorax fuscus Fowler
Previously referred to as *Glyptothorax major* by P.K.L. Ng & Lim (1996: 112). However, *G. major* appears to be restricted to Borneo, and is a larger and more robust species. The local form should be called *G. fuscus*, a species described from southeastern Thailand (H.H. Ng, *pers. comm.*). There is an unconfirmed record of this fish in 1988 from a stream at Seletar Reservoir Park on the outskirts of Nee Soon Swamp Forest (Richard Yeong, *pers. comm.*). The specimen, however, was not retained.

Family Gobiidae

Pseudogobiopsis oligactis (Bleeker)
We have not been able to find *Pseudogobiopsis oligactis* in recent surveys. All recent goby specimens collected from the Central Catchment Nature Reserve and other inland freshwaters by the authors and their colleagues have been the introduced *Rhinogobius*.

Pseudogobiopsis siamensis (Fowler)
There was only one record of this species from the Nee Soon Swamp Forest area. Both *Pseudogobiopsis oligactis* and *P. siamensis* were misidentified as *Stigmatogobius poicilosoma* by Alfred (1966).

Introduced Taxa

Fishes discussed under this section (Table 3) are present in the wild state through human intervention. They may be foreign species, which are native to South America or Africa, or even taxa that have been recorded as indigenous fauna in the past and presently regarded as extinct as they were not recorded by Alfred (1966) in his fairly thorough survey of the island's freshwater fish fauna. Their presence strongly indicates introduction by human means (e.g., *Hampala macrolepidota*). The aquarium fish trade and the food fish trade are the main contributors to the alien fish diversity in Singapore. Many species have adapted well to conditions independent of human husbandry, and have established self-sustaining populations in the

wild. However, their survival may not be long-term. For instance, *Rasborinus lineatus*, which was once common in Singapore and occurred in areas now under the Nature Reserves, appears to have died out (P.K.L. Ng & Lim, 1996). The species listed have either established thriving populations in the Nature Reserves, or have good potential of doing so as they are found in similar habitats and occur naturally in neighbouring areas.

Table 3. List of known introduced species and their status in Singapore.
(Status: CU = cultured, ES = escapee, FE = feral (established), NA = native, EX = extinct
Use: AQ = aquarium fish, FF = food fish, IN = incidental (no use), PC = pest control)

No.	Species	Status	Use
	Family **OSTEOGLOSSIDAE**		
1.	*Scleropages formosus*	FE?	AQ
2.	*Osteoglossum bicirrhosum*	ES	AQ
	Family **NOTOPTERIDAE**		
3.	*Chitala ornata* *	FE?	AQ
	Family **CYPRINIDAE**		
4.	*Amblypharyngodon chulabornae*	ES	AQ?
5.	*Barbodes gonionotus*	CU	FF
6.	*Carasius auratus*	FE	FF
7.	*Cirrhinus molitorella*	CU	FF
8.	*Ctenopharyngodon idella*	CU	FF
9.	*Cyprinus carpio*	FE	AQ/FF
10.	*Esomus metallicus*	FE	AQ
11.	*Hampala macrolepidota*	ES?	AQ?
12.	*Hypopthalmichthys molitrix*	CU	FF
13.	*Hypopthalmichthys nobilis*	CU	FF
14.	*Leptobarbus hoeveni*	CU	FF
15.	*Osteochilus hasselti*	FE?	AQ?
16.	*Puntius binotatus*	FE	AQ?
17.	*Puntius conchonius*	ES	AQ
18.	*Puntius partipentazona*	FE	AQ
19.	*Puntius semifasciolatus*	FE	IN
20.	*Puntius tetrazona*	ES?	AQ
21.	*Rasbora borapetensis*	FE	AQ
22.	*Rasbora gracilis*	ES	AQ
23.	*Rasbora trilineata*	ES	AQ
24.	*Rasborinus lineatus*	EX	IN

No.	Species	Status	Use
	Family **CHARACIDAE**		
25.	*Colossoma macropomum*	CU	FF/AQ
26.	*Paracheirodon innesi*	ES	AQ
	Family **PANGASIIDAE**		
27.	*Pangasius hypophthalmus*	CU	FF/AQ
	Family **PIMELODIDAE**		
28.	*Phractocephalus hemioliopterus* *	ES	AQ
	Family **CALLICHTHYIDAE**		
29.	*Corydoras aeneus*	ES	AQ
	Family **LORICARIIDAE**		
30.	*Liposarcus pardalis*	FE	AQ
	Family **POECILIIDAE**		
31.	*Poecilia reticulata*	FE	AQ/PC
32.	*Poecilia sphenops*	FE	AQ
33.	*Poecilia latipinna*	FE?	AQ
34.	*Xiphophorus helleri*	ES	AQ
35.	*Xiphophorus maculatus*	FE?	AQ
36.	*Gambusia holbrookii*	FE	AQ/PC
	Family **AMBASSIDAE**		
37.	*Parambassis siamensis*	FE	AQ/IN
	Family **CICHLIDAE**		
38.	*Astronotus ocellatus*	ES	AQ
39.	*Cichla ocellaris*	FE?	AQ
40.	*Oreochromis aureus*	ES	FF
41.	*Oreochromis mossambicus*	FE	FF
42.	*Oreochromis niloticus*	ES	FF
43.	*Thorichthys meeki*	ES	AQ
44.	*Tilapia zillii*	FE?	FF
	Family **GOBIIDAE**		
45.	*Rhinogobius giurinus*	FE	IN
	Family **OSPHRONEMIDAE**		
46.	*Betta splendens*	ES	AQ
47.	*Osphronemus goramy*	FE	FF
48.	*Sphaerichthys osphromenoides*	ES	AQ
49.	*Trichogaster microlepis*	FE?	AQ
50.	*Trichogaster pectoralis*	FE	FF

No.	Species	Status	Use
	Family **CHANNIDAE**		
51.	*Channa micropeltes*	CU/FE	FF
	Family **MASTACEMBELIDAE**		
52.	*Macrognathus siamensis*	ES	AQ

* The Clown Knifefish, *Chitala ornata*, a native of Thailand, was reported from the Sungei Seletar Reservoir where some ten examples were obtained (but not kept) by rod and line in early 1998 (Tan Yit Wee, *pers. comm.*). There is a record of a 4 ft. (25 kg) Red-tailed Catfish, *Phractocephalus hemioliopterus*, native to tropical South America, fished off the Pandan River in 1996 (Lianhe Wanbao, 4 Aug. 1996: 4&8 with photographs). Being popular aquarium fish that attain large eventual sizes, they may have been deliberately released when their owners could not cope.

Single individuals of *Puntius conchonius* (Cyprinidae) and *Macrognathus siamensis* (Mastacembelidae) have been recorded from streams in the CCNR. Specimens of Chinese major carps, for example, *Cyprinus carpio* and *Hypopthalmichthys nobilis*, can sometimes be observed in the reservoirs. These exotic species are frequently imported as food or aquarium fish. Occasionally, individuals may be encountered in the wild state, having escaped from ponds and cages, or released as unwanted aquarium pets. However, there is no evidence of them having established self-sustaining populations in the wild. They are therefore not included in the list.

Family Osteoglossidae

Scleropages formosus (Müller & Schlegel)
CCNR: Lower Peirce and MacRitchie Reservoirs.

Family Cyprinidae

Hampala macrolepidota Kuhl & van Hasselt
CCNR: Upper Peirce Reservoir (Robert Teo, *pers. comm.*, in 1998).
Although it was considered extinct in Singapore (Alfred, 1966), the present population seems most likely to be the result of deliberate introduction. As this is a common fish in streams and lakes throughout Peninsular Malaysia, it should adapt well to conditions in the Central Catchment reservoirs.

Osteochilus hasselti (Valenciennes)
CCNR: stream at Upper Seletar Reservoir Park.

Puntius partipentazona Fowler
CCNR: MacRitchie and Lower Peirce Reservoirs, and streams in Sime Road forest. BTNR: swamp along eastern boundary.

Puntius semifasciolatus (Günther)
CCNR: stream in Sime Road forest, Lower Peirce Reservoir.

Puntius tetrazona (Bleeker)
CCNR: stream in Upper Seletar Reservoir Park.

Rasbora borapetensis Smith
CCNR: stream in Upper Seletar Reservoir Park.

Family Loricariidae

Liposarcus pardalis (Castelnau)
CCNR: Lower Peirce and Upper Seletar Reservoirs.

Family Poeciliidae

Gambusia holbrookii (Girard)
CCNR: Lower Peirce Reservoir.

Poecilia reticulata Peters
CCNR and BTNR: present in exposed water bodies along peripheral areas.

Family Ambassidae

Parambassis siamensis (Fowler)
CCNR: Upper and Lower Peirce Reservoirs.

Family Cichlidae

Cichla ocellaris Bloch & Schneider
CCNR: Lower Peirce Reservoir.
Previously referred to as *Cichla* cf. *monoculus* (P.K.L. Ng & Lim, 1997: 123). This popular game and aquarium fish originates from South America.

Oreochromis mossambicus (Peters)
CCNR: present in all reservoirs and adjacent drainages.

Family Gobiidae

Rhinogobius giurinus (Rutter)
CCNR: Lower Peirce Reservoir, and a stream in the Upper Seletar Reservoir Park.
This species is native to China and Japan.

Family Osphronemidae

Osphronemus goramy Lacépède
CCNR: MacRitchie Reservoir.

Trichogaster pectoralis (Regan)
CCNR: Nee Soon Swamp Forest.

Family Channidae

Channa micropeltes (Cuvier)
CCNR: present in all reservoirs.

Conservation Status

The state of knowledge of Singapore's freshwater biodiversity is generally regarded as excellent (Kottelat & Whitten, 1996). This knowledge, together with Singapore's small size, makes conservation easier than is the case in most Asian countries. Over the past two decades, the landscape of Singapore has changed very drastically, and the pressures on natural fresh waters have been great (P.K.L. Ng, 1991, 1994; P.K.L. Ng & Lam, 1995). Many native species reported by Alfred (1966) have since become rare or perhaps even extinct. P.K.L. Ng *et al.* (1994) listed 18 extinct and 17 locally endangered species, and regarded three species as being possibly extinct. Moreover, the flourishing aquarium [which accounted for over S$80 million in 1994] (Ngiam, 1994; P.K.L. Ng & Tan, 1997) and food fish trade appear to have contributed more foreign species to the local fauna by way of deliberate or accidental introductions or escapees.

The list of extant native fish species known from Singapore thus now stands at 35 (Table 1), whilst the number of extinct species is 26 (Table 2). That is, 43% of Singapore's known native fish fauna is now extinct. It is

important to note that 21 of the 35 extant indigenous fish species (60%) are confined to waterways under forest cover. The five species that have recently become extinct (*Rasbora paucisqualis, Pangio semicincta, Glyptothorax fuscus, Pseudogobiopsis oligactis* and *P. siamensis*) were also collected mainly from the Nature Reserves. This strongly suggests that the loss of Singapore's forest over the last 150 years has contributed substantially to the loss of fish fauna on the island.

It is pertinent to note here that many of the extinct species are actually large river species and there are doubts as to whether they were actually found in Singapore at all. Many of these records are old [pre-World War II] (Herre & Myers, 1937) and are unsubstantiated. Singapore never had large rivers that could support large and typically riverine species like *Barbodes schwanenfeldii*, *Tor tambroides*, *Osteochilus melanopleura*, *Labiobarbus festivus*, *Hampala macrolepidota* (Cyprinidae), *Micronema micronema*, *Wallago leerii* (Siluridae) and *Hemibagrus nemurus* (Bagridae), and there is every chance that the specimens on which the old records are based actually came from neighbouring Peninsular Malaysia.

Of the extant species, 21 of the 35 species are present only in the Nature Reserves which illustrates the crucial importance of the Nature Reserves for the contiuned existence of these species (Table 1). More worrying is that the Nee Soon Swamp Forest has a disproportionately large number of native species, which are only known from or have their major populations there. Eight species (*Puntius hexazona*, *Nemacheilus selangoricus*, *Pangio shelfordii*, *Silurichthys hasselti*, *Pseudomystus rugosus*, *Parakysis longirostris*, *Channa melasoma* and *Macrognathus maculatus*) are only known from this area while another three species (*Rasbora heteromorpha*, *Luciocephalus pulcher* and *Channa gachua*) have their major populations in the Nee Soon Swamp Forest (P.K.L. Ng & Lim, 1992). As it now stands, with the Nee Soon Swamp Forest suffering from possible excess drainage etc., some species would likely become extinct over the next few decades. Prime candidates for extinction because of their apparently fastidious habitat requirements and current low populations would be *Nemacheilus selangoricus*, *Pangio shelfordii*, *Silurichthys hasselti*, *Pseudomystus rugosus* and *Parakysis longirostris*. The threats to the native freshwater fish are thus particularly serious as all of them are primary freshwater species and most are very stenotopic in their habitat requirements.

About 52 introduced species have been recorded in Singapore's freshwaters, 17 of which have established feral populations here (Table 3). This is a substantial number, considering that Singapore's extant indigenous freshwater fish fauna is only 35 species. Despite the large proportion of introduced fauna, it has not been shown that they have caused substantial

reduction in population size or the extinction of any native species (P.K.L. Ng *et al.*, 1993).

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The Conservation Status of Freshwater Prawns and Crabs in Singapore with Emphasis on the Nature Reserves

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Abstract

The freshwater prawn and crab fauna of Singapore are well studied, and 23 species have been reported. Seven species of freshwater crabs are present, of which three species, *Parathelphusa reticulata* (Parathelphusidae), *Irmengardia johnsoni* (Parathelphusidae), and *Johora singaporensis* (Potamidae) are endemic to Singapore. Sixteen species of freshwater prawns are known, but two species, *Macrobrachium scabriculum* and *M. rosenbergii* (Palaemonidae) are now believed to be extinct. Eight species had originally been described from Singapore. The possibility of species entering the catchment area through the import of raw water into Singapore from Malaysia is discussed.

Introduction

The freshwater decapod prawns and crabs (Decapoda, Crustacea) of Singapore have been studied intensely over the last 30 years, and are well known by any standard (Ng, 1990). In a recent appraisal of the state of freshwater biodiversity in Asia, Singapore was singled out as one country in which its freshwater fauna was very well known and studied in depth (Kottelat & Whitten, 1996).

The present paper is intended to review and provide a synopsis of the extant and extinct freshwater decapod crustacean fauna of Singapore with particular reference to the Nature Reserves. It will also examine how the continued conservation of the remaining forests in the centre of the island (i.e., the Nature Reserves) is critical for the long-term survival of the majority of the extant decapod crustacean fauna.

State of the Prawn Fauna

The freshwater prawn and crab fauna of Singapore were recently reviewed by Ng (1990), who recognised 24 species, of which 22 were regarded as indigenous. Since then, three new species have been added to the fauna. Choy and Ng (1991) described *Caridina temasek*, a species that was only

identified as *Caridina* sp. by Ng (1990). Ou and Yeo (1995) showed that specimens which had been identified as *Macrobrachium pilimanus* by Johnson (1961a) and Ng (1990) were actually new to science and named it *M. platycheles*. Most recently, Yeo and Ng (1997) added *Potamalpheops amnicus*, the first record of a freshwater snapping prawn (Alpheidae) from Singapore. A total of 23 native species of freshwater decapod crustaceans are thus now known from Singapore (Tables 1, 2).

Table 1. Extant Native Freshwater Decapod Crustaceans.
(EN = Endangered, CO = Common, FO = Forest waters, OP = Open waters, NSS = Nee Soon Swamp Forest, BTNR = Bukit Timah Nature Reserve, NR = Nature Reserves (excluding NSS & BTNR), OA = Open areas, + = present, - = absent)

	Species	Status	Habitat	NSS	BTNR	NR	OA
	Family **POTAMIDAE**						
1.	*Johora singaporensis*	EN	FO	-	+	-	-
	Family **PARATHELPHUSIDAE**						
2.	*Parathelphusa maculata*	CO	FO/OP	+	-	+	+
3.	*Parathelphusa reticulata*	EN	FO	+	-	-	-
4.	*Irmengardia johnsoni*	EN	FO	+	+	+	-
	Family **GRAPSIDAE**						
5.	*Varuna yui*	CO	OP	-	-	-	+
6.	*Geosesarma peraccae*	EN	FO	+	+	+	-
7.	*Geosesarma nemesis*	EN	FO	-	+	-	-
	Family **PALAEMONIDAE**						
8.	*Macrobrachium malayanum*	CO	FO	+	+	+	-
9.	*Macrobrachium platycheles*	EN	FO	+	-	-	-
10.	*Macrobrachium trompii*	EN	FO	+	-	+	-
11.	*Macrobrachium sintangense*	CO	OP/FO	-	-	+	+
12.	*Macrobrachium neglectum*	EN	FO	+	-	-	-
13.	*Macrobrachium idae*	EN	OP	+	-	+	-
14.	*Macrobrachium equidens*	CO	OP	-	-	-	+
	Family **ATYIDAE**						
15.	*Caridina temasek*	EN	FO	-	-	+	-
16.	*Caridina gracilirostris*	EN	FO/OP	+	-	-	-
17.	*Caridina propinqua*	CO	FO/OP	-	-	+	+
18.	*Caridina simoni peninsularis*	EN	FO/OP	-	-	+	+
19.	*Caridina tonkinensis*	EN	FO/OP	-	-	+	+
20.	*Caridina weberi sumatrensis*	EN	FO/OP	-	-	+	+
	Family **ALPHEIDAE**						
21.	*Potamalpheops amnicus*	EN	FO	-	-	+	-

Two of the species (both palaemonids) are now regarded as extinct (Table 2), representing about 9% of the total known native fauna. *Macrobrachium scabriculum* has not been reported since early this century and must be regarded as extinct (Johnson, 1961a). The specimens on which this record was based were recently re-examined and their identity was confirmed (Y. Cai, *pers. comm.*). The extinction of the well known Giant Prawn or Udang Galah, *M. rosenbergii*, is a more recent phenomenon, as juveniles were still seen as late as 1985 in the streams draining into Nee Soon (Ng, 1990). This area is now very disturbed, with the lower stretches highly polluted. No individuals have, however, been seen or recorded since, and the species is now regarded as extinct. Both these species have small eggs and pelagic larvae that develop in estuarine and coastal areas, with the young prawns having to swim upstream to their adult habitats. Pollution, concretisation and changes in almost all estuarine areas in Singapore mean that the survival of these species is doubtful. The same problems are also faced by two other species, *Macrobrachium neglectum* and *M. idae*. Both species were still relatively common in the early 1980s in streams outside the Nee Soon Swamp Forest, but they have become very rare in recent years. Both species have small eggs and pelagic larvae that must develop downstream. The loss and/or modification of downstream habitats have apparently contributed to their population decrease, and both species are likely to become extinct in the near future, regardless of how much of our forests are conserved.

Table 2. Extinct Freshwater Decapod Crustaceans of Singapore.
(FO = Forest waters, OP = Open waters, LRF = large river fauna, + = present, - = absent)

	Species	Habitat	LRF
	Family **PALAEMONIDAE**		
1.	*Macrobrachium scabriculum*	OP/FO	-
2.	*Macrobrachium rosenbergii*	OP/FO	+

For the three atyid shrimps, *Caridina simoni peninsularis*, *C. tonkinensis* and *C. weberi sumatrensis*, none has been collected from Singapore waters since the reports by Johnson (1961a, b) and they might no longer be extant. If they are present, they should be regarded as highly endangered. All three are freshwater species that have their larval development linked to estuarine areas as well.

Of the extant shrimp species, most of the endangered species have direct or semi-abbreviated larval developments, that is, they can complete their development within the waters of the catchment area. Of these, the two most vulnerable species are *Macrobrachium platycheles* and *M. trompii*. *Macrobrachium platycheles* is known only from the forested, faster flowing streams in the Nee Soon Swamp Forest, whilst *M. trompii* only occurs in the more acidic waters of the same swamp.

State of the Crab Fauna

Of the freshwater crabs, *Varuna yui* is a eurytopic species that is essentially a marine crab that can live in freshwater. Of the true freshwater crabs (i.e., species that have semi- to completely abbreviated larval development), all species are threatened to various degrees by ongoing and potential habitat loss.

Of the six extant wholly freshwater species, three (*Parathelphusa maculata*, *Geosesarma peraccae* and *G. nemesis*) are also common in Peninsular Malaysia, with *P. maculata* and *G. peraccae* still relatively common in Singapore in some areas at the edge of the catchment area. Three species, *I. johnsoni*, *P. reticulata* and *J. singaporensis*, are endemic to Singapore (Ng, 1988, 1989). Studies of neighbouring areas (e.g., southern Malaysia and Riau Archipelago) have revealed allied but clearly different species that strongly support the consensus that these three species are true Singapore endemics.

The most vulnerable of these three is *P. reticulata*, which is known only from a small patch of swamp in the Nee Soon Swamp Forest (Ng & Lim, 1992). *Johora singaporensis* is known only from Bukit Timah Nature Reserve and a small stream at the edge of the catchment area (near Bukit Batok Nature Park). The main population is in Bukit Timah Nature Reserve, where it is now threatened by the gradual drying up of the streams there (Ng, 1995). Although no freshwater crab species is yet known to have become extinct in Singapore, *P. reticulata* and *J. singaporensis* are the most likely candidates in the decades ahead due to their stenotopic habitat requirements and restricted ranges.

Note on Introductions

There are some problems with a few species that are now still regarded as native. The shrimps *Caridina temasek* and *Potamalpheops amnicus* are known only from one stretch of Sime Road in the Central Catchment Nature Reserve, an area in which raw, untreated water from Johor is

regularly pumped in to supplement the water stock in the reservoirs. It is possible that these two shrimps may have entered Singapore this way. It is pertinent to note that both shrimps are small species (up to 10 mm in length) and the adults or young could have easily crossed the filters normally placed in water pipes. The two shrimps had not been listed in any of the earlier works on Singapore shrimps by Johnson (1960, 1961a, b), and both species can be common in parts of western Johor (Yeo & Ng, 1997), from where much of Singapore's water comes.

There is as yet, however, no compelling evidence that the two species are definitely not part of Singapore's original fauna, as the habitats for both taxa are not very specific. In addition, *P. amnicus* is a very difficult species to collect by normal methods as it is not only very small (and therefore easily mistaken for the young of other common prawns) but it also lives deep in burrows in eroded banks (Yeo & Ng, 1997). This species could thus have been missed by earlier workers. For the moment, it seems best to regard them as part of Singapore's extant native fauna.

With regards to introduced crustacean species in Singapore, there appears to be no obvious problems for the native fauna at present. This is probably due to the fact that the majority of the extant native species are forest inhabitants living in softer and more acidic waters, while successful introductions have mainly been more open-country and hard water species (Ng *et al.*, 1993).

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Butterfly Biodiversity in Singapore with Particular Reference to the Central Catchment Nature Reserve

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Abstract

A total of 381 butterfly species have now been recorded in Singapore of which 18 are new records since 1990. Of this total, 236 species (62%) were recorded during the present survey. All except 8 (3%) of these occur within the Nature Reserves and 148 (63%) were recorded only within the Nature Reserves. A total of 74 species (31%) within the Reserves were considered very rare.

Introduction

The study of butterflies by amateurs is not new, and indeed, it is through the observations of these dedicated individuals that much important data have been accumulated over the years. The information on butterfly biodiversity in Singapore is, at most, sketchy. Most of the documentation of the species occurred done during the post-war years until the late 1960s. From our literature research, two references stand out: W.A. Fleming's Butterflies of West Malaysia and Singapore (1991) and Steven Corbet and Maurice Pendlebury's Butterflies of the Malay Peninsula (1992). Although the latest editions of the two reference books were published in the early 1990s, most of the updates referred only to the Peninsular Malaysia. Collating data from these reference books, the last known total species count for Singapore Island was 363 (Corbet & Pendlebury, 1992).

Only recently has a concerted effort been made to study and establish the status of butterfly biodiversity in Singapore. This paper presents our observations and findings with particular reference to the Central Catchment Nature Reserve. With continued support from the National Parks Board there is an opportunity to undertake a long-term butterfly biodiversity survey in Singapore so that the knowledge of the status of species of butterflies will increase and a greater understanding of these beautiful creatures will be established.

Methods

Field surveys were conducted from 1990 to 1997 in and around various

areas in Singapore. In particular, many of the surveys were concentrated within and around the Central Catchment Nature Reserve. For the surveys, we used a simple method of selecting sites based on available information of known or marked routes. Field surveys were based on visual identification but where necessary, specimens were captured for closer inspection and subsequently released, or were kept in a reference collection. Where possible, the number of individuals was noted, and other observations like male/female or special activities were also documented. However, it should be noted that for two of the families, Lycaenidae and Hesperiidae, there are limitations to field identification, and even in a set reference collection, the correct identification of certain species may be difficult. Whilst all attempts have been made to identify the species correctly, it is hoped that the data from future surveys and scientific studies will provide opportunities for counterchecking and confirmation.

Results and Discussion

To establish a reference database on the butterfly biodiversity in Singapore, a comprehensive checklist of the species observed during the last seven years has been compiled (Table 1). Of the 363 species previously known species in Singapore, a total of 218 (or 60%) was accounted for. A further 18 new records were observed, making a total of 236 extant species (Appendix 1). Not all species were located within the Central Catchment Nature Reserves.

Summary Analysis by Family

About 60% of the species previously identified as existing in Singapore can still be found. Many of the larger and showy species are still evident, although some species are extremely rare with only a few individuals observed. The family Papilionidae (Plate 1a–f) is currently represented by 13 species in Singapore. It can be safely concluded that two species, Malayan Birdwing *Troides amphrysus ruficollis* and Great Blue Mime *Chilasa paradoxa aenigma*, recorded earlier have since become extinct. A surprising find is Blue Helen *Papilio prexaspes prexaspes*. It is highly unlikely that the earlier authors missed such a large butterfly. We can only speculate that the species has migrated south from Peninsular Malaysia and has since established a small colony.

The family Pieridae seems to have suffered a significant drop in biodiversity over the years. Only 15 out of the original 23 species still survive in Singapore. However, the *Eurema* species, particularly, Common

Table 1. Survey of Butterfly Biodiversity – Species Count.

Family	Subfamily	Literature Records (A)	Sighted during survey period (B)	% of Original (C)	New Records (D)	Extant no. of species (B + D)	Total recorded for Singapore (A + D)
Papilionidae	Papilioninae	14	12	85.7	1	13	15
Pieridae	Pierinae	11	6	54.5	0	6	11
	Coliadinae	12	9	75.0	0	9	12
Nymphalidae	Danainae	18	13	72.2	0	13	18
	Satyrinae	17	16	94.1	1	17	18
	Morphinae	7	5	71.4	0	5	7
	Nymphalinae	51	37	72.5	4	41	55
	Charaxinae	5	2	40.0	0	2	5
Lycaenidae	Riodininae	6	3	50.0	0	3	6
	Poritiinae	3	2	66.7	0	2	3
	Miletinae	13	6	46.2	0	6	13
	Curetinae	5	2	40.0	0	2	5
	Lycaeninae	132	64	48.5	5	69	137
Hesperiidae	Coeliadinae	10	8	80.0	0	8	10
	Pyrginae	8	6	75.0	3	9	11
	Hesperiinae	51	27	52.9	4	31	55
TOTAL		**363**	**218**	**58.6**	**18**	**236**	**381**

Grass Yellow *Eurema hecabe contubernalis* enjoys the distinction of being the most common butterfly in Singapore and can often be found in abundance.

The family Nymphalidae is represented by 5 subfamilies in Singapore. A total of 13 species of the subfamily Danainae (Plate 2a–b) can still be found in Singapore. Most of these species can often be found swarming around flowering trees, e.g., *Syzygium* spp. (Myrtaceae) in the Nature Reserves. One species, Plain Tiger *Danaus chrysippus chrysippus* (Plate 2b) is decidedly local and can be found only in a few suburban locations. The subfamily Satyrinae (Plate 2c, d) records a healthy 94% of the original species known to exist in Singapore. Furthermore, one new record *Mycalesis perseoides perseoides* has been added to the Singapore checklist. Of notable interest is *Elymnias penanga penanga*, which still survives but only on Pulau Ubin. Most of the species in this subfamily feed on grasses,

bamboo, palms and other monocotyledons. Five of the original seven of the subfamily Morphinae still exist in Singapore, although most are forest butterflies that have become quite rare. As many of the species are attracted to fruit bait, it would be interesting to conduct bait trap experiments to establish the density of these species. Dark Blue Jungle Glory *Thaumantis klugius lucipor* is one of the most beautiful butterflies in the region, comparable to the *Morpho* of South America. The life history of the species is still unknown, although we suspect that it feeds on rattan or another palm. The subfamily Nymphalinae (Plate 3a–c) records a total of 37 of the original 51 species that existed in Singapore. The majority of the species can be found in the nature reserves. It is interesting to note that we have observed four new records, Lace Sergeant *Athyma pravara helma*, Plain Lacewing *Cethosia penthesilia methypsea*, *Neptis harita harita* and *Lexias dirtea merguia* (Plate 3c) for Singapore. One species, *Neptis harita harita* is restricted in distribution, and can only be found in the Mandai area. It is likely that this species migrated from Malaysia in recent years and the colony in Singapore is highly dependent on a hitherto unknown food plant somewhere in the northern part of Singapore. Only two of the original five species of the subfamily Charaxinae (Plate 3d) have been observed in Singapore recently. Both species are rather rare and are not often seen. Although the Blue Nawab *Polyura schreiber tisamenus*, is known to feed on leaves of the common rambutan, it has become extremely rare, as the food plant has seen a significant loss in popularity as a garden fruit tree in recent years, and also there have been severe changes in its favoured habitat.

The family Lycaenidae (Plates 4a–d, 5a–c) includes the largest number of species in both Malaysia and Singapore. Of the originally recorded 159 species, we have observed only 77 to date. However, many of the species in this family are difficult to identify with certainty, particularly in the genera *Arhopala, Jamides, Allotinus* and *Nacaduba.* Further intensive research and field collection would probably yield a greater number of species that have not been recorded in recent years.

Finally, the family Hesperiidae (Plate 5d–e), with 41 of the original 69 species found in Singapore, may also yield more species when more collecting data are available. It is interesting to note that we have discovered a total of seven new records for Singapore – the highest number of new records amongst the five butterfly families in Singapore.

Some Observations on Singapore Butterflies and Their Host Plants

The interrelation between butterflies and their caterpillar host plants cannot

be understated. Many species depend solely on one particular species of plant and will obviously become extinct, if the host plant is no longer available.

Interestingly, the adaptation of certain species is remarkable, in that due to some evolutionary process, these species have been found to feed on other plants. One such case is the species Common Faun *Faunis canens arcesilas*. From established literature (Corbet & Pendlebury, 1992), this species was reported to feed on a species of wild banana (*Musa sp.*). However, we have discovered that the species in Singapore feeds on Fish Tail Palm (*Caryota mitis,* Arecaceae).

Another species, The Common Tit *Hypolycaena erylus teatus* (Plate 5c), was known to feed on *Vangueria spinosa* (Rubiaceae) and *Cinnamomum verum* (Lauraceae), (Corbet & Pendlebury, 1992). However, we made a startling find here in Singapore, when we discovered the caterpillars of this species, feeding on Javanese Ixora (*Ixora javanica,* Rubiaceae), planted at the road shoulder along busy Victoria Street in downtown Singapore!

Eurema species, on the other hand, have been found on several types of Leguminosae such as *Cassia, Acacia, Caesalpinia* and *Albizia.* The species' versatility in their host plants seem to explain why they are often abundant in many areas in Singapore. It is interesting to note that the species Common Grass Yellow *Eurema hecabe contubernalis*, does not seem to have any preference for large- or small-leafed plants. We have seen a female of the species lay her eggs on both Peacock Flower (*Caesalpinia pulcherrima*, Leguminosae) and Seven Golden Candlesticks (*Cassia alata*, Leguminosae) planted in adjacent pots. The caterpillars were bred to adulthood with no apparent difference or distinction in size or colouration.

Orange Emigrant *Catopsilia scylla scylla* appears to be confined to urban areas where its host plant, *Cassia biflora*, is grown as a roadside tree. It is not unusual to find the butterfly, which is fast on the wing, darting between the rush hour traffic along Shenton Way. We have not encountered this species in the Nature Reserves.

Some Observations on Habitats and Feeding Preferences of Singapore Butterflies

Many butterflies species that we recorded during the surveys were observed whilst feeding. Favourite flowering bushes of many species of butterflies are Prickly Lantana (*Lantana camara*, Verbenaceae), Singapore Rhododendron (*Melastoma malabathricum*, Melastomataceae), Common

Asystasia (*Asystasia gangetica* spp. *micrantha*, Acanthaceae), Mile-a-Minute (*Mikania micrantha*, Compositae) and Common Snakeweed (*Stachytarpheta indica*, Verbenaceae). Occasionally, we encountered a flowering tree in the Nature Reserves, which was literally swarmed with butterflies. Some of the *Syzygium* species when in full bloom are particularly attractive to butterflies. Species of the families Papilionidae, Pieridae and Nymphalidae are attracted to roadside seepages and damp muddy banks where they imbibe the liquid nutrients from the ground.

Many species are also attracted to rotting fruit like pineapple, papaya and banana and certain species of butterflies feed on rotting fruits of figs (*Ficus* spp.) on the forest floor. Of particular interest is the Dark Blue Jungle Glory *Thaumantis klugius lucipor*, one of the most beautiful species of the Morphinae subfamily, which is reported to avoid fruit bait (Corbet & Pendlebury, 1992). However, we have observed an individual female of this species feeding on the rotting berries on the forest floor. This suggests that it can be captured with a bait trap, provided that its preferred menu is offered.

Several species of the subfamily Danainae are attracted to dried plants of Indian Heliotrope (*Heliotropium indicum*, Boraginaceae).

Conclusions

Although the biodiversity of butterflies in Singapore may be considered fair, a number of species observed were represented by only a single specimen. There is cause for more effort on the conservation of remaining nature reserves in Singapore to maintain what is left of the flora on which the butterflies depend on for survival. As studies on identifying the host plants for the different species of butterflies is far from complete, it is necessary to conserve as much plant biodiversity in the Nature Reserves as possible.

For the known host plants, it would be useful to identify possible locations where these species may be planted without danger of being sprayed with pesticides and other chemicals that are harmful to the caterpillars and egg-laying females. Whilst the Nature Reserves would be the obvious choice for establishing these plants, urban and suburban areas may also be considered. Some examples of roadside trees e.g., *Cassia fistula, Cassia biflora, Cerbera odollam* (Apocynaceae) and others are already supporting certain species in the public housing areas. "Butterfly gardens" could be incorporated into school ecogardens, government-owned premises such as bin centres, power substations and other utility buildings – where the plants could be cultivated and left to be eaten by the caterpillars without

too much concern for the aesthetic appearance of the plants themselves. Even a small area of the Singapore Botanical Gardens could be set aside to cultivate insecticide-free host plants.

If the cultivation of host plants is more widespread, there will also need to be adequate flowering plants to support the adult butterflies. In this case, there is less concern about where these flowering plants could be grown. In fact, our parks and green areas are ideal for planting *Ixora, Lantana camara,* and other nectar-rich flowering plants that the adult butterflies depend on for sustenance.

There is also scope for a pilot study on the re-introduction of some of the more spectacular species of butterflies that have become extinct in Singapore. For example, we could import the pupae of the "birdwing" species Malayan Birdwing *Troides amphrysus ruficollis* and release the adult butterflies in areas where its food plant Dutchman's Pipe *Aristolochia tagala*, is cultivated and monitor the survival rate of the species. As the host plant is indigenous, it does no threat to Singapore's flora. However, care must be taken to ensure that the re-introduction will not be at the expense of existing species of butterflies which share the same host plant.

There is still much to learn and do, and we hope that this paper will help in a small way to increase the knowledge of our butterflies and to help preserve them for Singapore's future generations.

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Appendix 1. Checklist of Butterflies in Singapore.

Legend for Status
Very Rare - An average of 1–5 individuals observed per year
Rare - An average of 6–20 individuals observed per year
Common - An average of 21–50 individuals observed per year
Very Common - An average of 51 or more individuals observed per year

Legend for Habitat
1. Not present in the Nature Reserves
2. Present in the Reserves and other Locations Outside the Nature Reserves
3. Present Only in the Nature Reserves
4. Largely Confined to the Reserves with an Occasional Record Outside the Nature Reserves

No.	Species	Common Name	Status	Habitat
	Family **PAPILIONIDAE** — Subfamily **PAPILIONINAE**			
1.	*Chilasa clytia clytia*	Common Mime	Rare	2
2.	*Graphium agamemnon agamemnon*	Tailed Green Jay	Common	2
3.	*Graphium evemon eventus*	-	Very Common	4
4.	*Graphium sarpedon luctatius*	Common Bluebottle	Very Common	4
5.	*Pachliopta aristolochiae asteris*	Common Rose	Rare	2
6.	*Papilio demoleus malayanus*	Lime Butterfly	Very Common	2
7.	*Papilio demolion demolion*	Banded Swallowtail	Rare	2
8.	*Papilio iswara iswara*	Great Helen	Rare	3
9.	*Papilio memnon agenor*	Great Mormon	Common	2
10.	*Papilio polytes romulus*	Common Mormon	Very Common	2
11.	***Papilio prexaspes prexaspes***	Blue Helen	Very Rare	3
12.	*Pathysa antiphates itamputi*	Five Bar Swordtail	Rare	3
13.	*Troides helena cerberus*	Common Birdwing	Rare	2
	Chilasa paradoxa aenigma	Great Blue Mime	Extinct	
	Troides amphrysus ruficollis	Malayan Birdwing	Extinct	
	Family **PIERIDAE** — Subfamily **PIERINAE**			
14.	*Appias libythea olferna*	Striped Albatross	Very Common	2
15.	*Appias lyncida vasava**[1]	Chocolate Albatross	Very Rare	2
16.	*Delias hyparete metarete*	Painted Jezebel	Very Common	2
17.	*Delias pasithoe parthenope**[2]	-	Very Rare	1
18.	*Leptosia nina malayana*	Psyche	Rare	2
19.	*Pieris canidia malayica*	Cabbage White	Common	1
	Appias nero figulna	Orange Albatross	Extinct	
	Cepora iudith malaya	Orange Gull	Extinct	
	Delias singhapura singhapura	-	Extinct	
	Pareronia valeria lutescens	Wanderer	Extinct	
	Saletara liberia distanti	Malayan Albatross	Extinct	

No.	Species	Common Name	Status	Habitat
	Family **PIERIDAE** — Subfamily **COLIADINAE**			
20.	*Catopsilia pomona pomona*	Common Emigrant	Very Common	2
21.	*Catopsilia pyranthe pyranthe*	Mottled Emigrant	Rare	2
22.	*Catopsilia scylla scylla*	Orange Emigrant	Common	1
23.	*Eurema andersonii andersonii*	-	Rare	3
24.	*Eurema blanda snelleni*	Three Spot Grass Yellow	Very Common	2
25.	*Eurema hecabe contubernalis*	Common Grass Yellow	Very Common	2
26.	*Eurema sari sodalis*	Chocolate Grass Yellow	Very Common	2
27.	*Eurema simulatrix tecmessa*	-	Very Common	2
28.	*Gandaca harina distanti*	Tree Yellow	Common	3
	Dercas verhuelli herodorus	-	Extinct	
	Eurema ada iona	-	Extinct	
	Eurema brigitta senna	-	Extinct	
	Family **NYMPHALIDAE** — Subfamily **DANAINAE**			
29.	*Danaus chrysippus chrysippus*[*3]	Plain Tiger	Very Rare	2
30.	*Danaus genutia genutia*	Common Tiger	Common	2
31.	*Danaus melanippus hegesippus*	Black Veined Tiger	Rare	2
32.	*Euploea camaralzeman malayica*[*4]	Malayan Crow	Very Rare	3
33.	*Euploea crameri bremeri*	Spotted Black Crow	Rare	4
34.	*Euploea eyndhovii gardineri*	Striped Black Crow	Rare	3
35.	*Euploea midamus singapura*	Spotted Blue Crow	Rare	4
36.	*Euploea mulciber mulciber*	Striped Blue Crow	Common	2
37.	*Euploea phaenareta castelnaui*	King Crow	Common	2
38.	*Euploea radamanthus radamanthus*	Magpie Crow	Common	4
39.	*Idea stolli logani*	Common Tree Nymph	Common	3
40.	*Ideopsis vulgaris macrina*	Blue Glassy Tiger	Very Common	2
41.	*Parantica agleoides agleoides*	Dark Glassy Tiger	Very Common	2
	Euploea eunice lencogonis	Blue Branded King Crow	Common	3
	Euploea tulliolus ledereri	Dwarf Crow	Extinct	
	Idea leuconoe chersonesia	White Tree Nymph	Extinct	
	Ideopsis gaura perakana	Lesser WoodNymph	Extinct	
	Parantica aspasia aspasia	Yellow Glassy Tiger	Extinct	
	Family **NYMPHALIDAE** — Subfamily **SATYRINAE**			
42.	*Elymnias hypermnestra agina*	Common Palmfly	Very Common	2
43.	*Elymnias panthera panthera*	Tawny Palmfly	Rare	3
44.	*Elymnias penanga penanga*[*5]	-	Very Rare	1
45.	*Lethe europa malaya*	Bamboo Tree Brown	Very Rare	3
46.	*Melanitis leda leda*	Common Evening Brown	Rare	2

No.	Species	Common Name	Status	Habitat
47.	*Mycalesis fusca fusca*	Malayan Bush Brown	Rare	3
48.	*Mycalesis mineus macromalayana*	Dark Brand Bush Brown	Very Common	2
49.	*Mycalesis orseis nautilus*	Purple Bush Brown	Rare	3
50.	***Mycalesis perseoides perseoides***	-	Rare	2
51.	*Mycalesis perseus cepheus*	-	Common	2
52.	*Mycalesis visala phamis*	-	Rare	3
53.	*Orsotriaena medus cinerea*	Nigger	Very Common	2
54.	*Ypthima baldus newboldi*	Common Five Ring	Common	2
55.	*Ypthima fasciata torone*[*6]	-	Very Rare	3
56.	*Ypthima horsfieldi humei*[*7]	-	Very Rare	3
57.	*Ypthima huebneri*	Common Four Ring	Very Common	4
58.	*Ypthima pandocus corticaria*	Common Three Ring	Very Common	2
	Elymnias esaca esaca	-	Extinct	
	Family **NYMPHALIDAE** — Subfamily **MORPHINAE**			
59.	*Amathusia phidippus phidippus*	Palm King	Rare	4
60.	*Discophora sondaica despoliata*[*8]	-	Very Rare	3
61.	*Faunis canens arcesilas*	Common Faun	Common	3
62.	*Thaumantis klugius lucipor*	Dark Blue Jungle Glory	Very Rare	3
63.	*Zeuxidia amethystus amethystus*	Saturn	Common	3
	Thaumantis noureddin noureddin	Dark Jungle Glory	Extinct	
	Zeuxidia doubledayi doubledayi	-	Extinct	
	Family **NYMPHALIDAE** — Subfamily **NYMPHALINAE**			
64.	*Athyma asura idita*	-	Very Rare	3
65.	*Athyma kanwa kanwa*	-	Very Rare	3
66.	*Athyma nefte subrata*	Colour Sergeant	Rare	3
67.	***Athyma pravara helma***	**Lance Sergeant**	Very Rare	3
68.	*Athyma reta moorei*	-	Very Rare	3
69.	*Cethosia hypsea hypsina*	Malay Lacewing	Very Common	4
70.	***Cethosia penthesilia methypsea***[*9]	**Plain Lacewing**	Very Rare	2
71.	*Chersonesia peraka peraka*[*10]	-	Very Rare	3
72.	*Cirrochroa orissa orissa*	Banded Yeoman	Very Rare	3
73.	*Cupha erymanthis lotis*	Rustic	Rare	3
74.	*Eulaceura osteria kumana*	-	Very Common	3
75.	*Euripus nyctelius euploeoides*	Courtesan	Rare	3
76.	*Euthalia aconthea gurda*	Baron	Very Rare	2
77.	*Euthalia adonia pinwilli*	-	Very Rare	3
78.	*Euthalia monina monina*	Malay Baron	Common	3
79.	*Hypolimnas anomala anomala*	Malayan Eggfly	Very Common	2
80.	*Hypolimnas bolina bolina*	Great Eggfly	Very Common	4
81.	*Hypolimnas misippus misippus*[*11]	-	Very Rare	3

No.	Species	Common Name	Status	Habitat
82.	*Junonia almana javana*	Peacock Pansy	Rare	2
83.	*Junonia atlites atlites*	Grey Pansy	Rare	2
84.	*Junonia hedonia ida*	Chocolate Pansy	Very Common	2
85.	*Junonia orithya wallacei*	Blue Pansy	Common	2
86.	*Lasippa heliodore dorelia*	-	Rare	3
87.	*Lasippa tiga siaka*	Burmese Lascar	Common	3
88.	*Lebadea martha parkeri*	Knight	Rare	4
89.	*Lexias canescens pardalina*	-	Very Rare	3
90.	***Lexias dirtea merguia***		Rare	3
91.	*Lexias pardalis dirteana*	Archduke	Very Common	3
92.	*Moduza procris milonia*	Commander	Very Common	3
93.	***Neptis harita harita****[12]	-	Rare	3
94.	*Neptis hylas papaja*	Common Sailor	Rare	4
95.	*Neptis leucoporos cresina*	-	Very Common	3
96.	*Pandita sinope sinope*	-	Rare	3
97.	*Pantoporia hordonia*	Common Lascar	Rare	3
98.	*Pantoporia paraka paraka*	-	Rare	3
99.	*Phaedyma columella singa*	Short Banded Sailor	Common	2
100.	*Phalantha phalantha phalantha*	Leopard	Common	2
101.	*Tanaecia iapis puseda*	Horsfield's Baron	Common	3
102.	*Tanaecia pelea pelea*	Malay Viscount	Very Common	4
103.	*Terinos terpander robertsia*	Royal Assyrian	Rare	3
104.	*Vindula dejone erotella*	Cruiser	Very Common	3
	Ariadne ariadne ariadne	Angled Castor	Extinct	
	Athyma perius perius	Common Sergeant	Extinct	
	Bassarona teuta goodrichi	Banded Marquis	Extinct	
	Chersonesia rahria rahria	Wavy Maplet	Extinct	
	Dophla evelina compta	-	Extinct	
	Euthalia djata rubidifascia	-	Extinct	
	Euthalia merta merta	-	Extinct	
	Neptis miah batara	-	Extinct	
	Pantoporia aurelia aurelia	-	Extinct	
	Pantoporia dindinga	-	Extinct	
	Pantoporia sandaka sandaka	-	Extinct	
	Parthenos sylvia lilacinus	Clipper	Extinct	
	Tanaecia godartii puloa	Malay Count	Extinct	
	Vagrans egista macromalayana	Vagrant	Extinct	
	Family **NYMPHALIDAE** — Subfamily **CHARAXINAE**			
105.	*Polyura hebe plautus*	-	Rare	3
106.	*Polyura schreiber tisamenus*	Blue Nawab	Very Rare	3
	Charaxes bernadus crepax	Tawny Rajah	Extinct	
	Polyura moori moori	-	Extinct	
	Prothoe franck uniformis	-	Extinct	
	Family **LYCAENIDAE** — Subfamily **RIODININAE**			
107.	*Abisara geza niya*	-	Rare	3

No.	Species	Common Name	Status	Habitat
108.	*Abisara savitri savitri*	-	Rare	3
109.	*Laxita thuisto thuisto*	Lesser Harlequin	Rare	3
	Abisara saturata kausambioides	Malayan Plum Judy	Extinct	
	Taxila haquinus haquinus	Harlequin	Extinct	
	Zemeros flegyas albipunctatus	Punchinello	Extinct	
	Family **LYCAENIDAE** — Subfamily **PORITIINAE**			
110.	*Poritia philota philota*	-	Very Rare	3
111.	*Poritia sumatrae sumatrae*	Sumatran Gem	Rare	3
	Simiskina phalia potina	Blue Brilliant	Extinct	
	Family **LYCAENIDAE** — Subfamily **MILETINAE**			
112.	*Allotinus unicolor unicolor*	Lesser Darkie	Rare	3
113.	*Logania marmorata damis*	-	Rare	3
114.	*Miletus biggsii biggsii*	Bigg's Brownie	Common	2
115.	*Miletus gopara gopara*	-	Rare	3
116.	*Miletus symethus petronius*[13]	-	Rare	3
117.	*Spalgis epius epius*	-	Very Rare	2
	Allotinus davidis	-	Extinct	
	Allotinus horsfieldi nessus	-	Extinct	
	Allotinus strigatus malayanus	-	Extinct	
	Allotinus substrigosus substrigosus	-	Extinct	
	Allotinus subviolaceus alkamah	-	Extinct	
	Liphyra brassolis abbreviata	The Moth Butterfly	Extinct	
	Miletus gaesa gaesa	-	Extinct	
	Family **LYCAENIDAE** — Subfamily **CURETINAE**			
118.	*Curetis santana malayica*	Malayan Sunbeam	Common	2
119.	*Curetis saronis sumatrana*[14]	-	Very Rare	1
	Curetis bulis stigmata	-	Extinct	
	Curetis regula	-	Extinct	
	Curetis sperthis sperthis	-	Extinct	
	Family **LYCAENIDAE** — Subfamily **LYCAENINAE**			
120.	*Acytolepis puspa lambi*	Common Hedge Blue	Common	3
121.	*Anthene emolus goberus*	Ciliate Blue	Rare	4
122.	*Anthene lycaenina miya*	-	Rare	4
123.	*Arhopala abseus abseus*	-	Rare	3
124.	*Arhopala aedias agnis*	Large Metallic Oak Blue	Rare	4
125.	*Arhopala ammon ammon*	-	Very Rare	3
126.	*Arhopala amphimuta amphimuta*	-	Very Rare	3
127.	*Arhopala antimuta antimuta*	-	Rare	3
128.	*Arhopala athada athada*	-	Rare	3
129.	*Arhopala atosia malayana*	Tailed Disc Oak Blue	Very Rare	3

No.	Species	Common Name	Status	Habitat
130.	*Arhopala aurea*	-	Rare	3
131.	*Arhopala epimuta epiala*	-	Rare	3
132.	***Arhopala major major***	-	Rare	3
133.	*Arhopala myrzala lammas*	-	Very Rare	3
134.	*Arhopala pseudocentaurus nakula*	-	Rare	2
135.	*Arhopala pseudomuta pseudomuta*	Raffles' Oak Blue	Rare	3
136.	*Arhopala trogon*[*15]	-	Very Rare	3
137.	*Caleta elna elvira*	Elbowed Pierrot	Rare	3
138.	*Castalius rosimon rosimon*[*16]	-	Very Rare	3
139.	***Catochrysops panormus exiguus***[*17]	**Silver Forget-Me-Not**	Very Rare	1
140.	*Catochrysops strabo strabo*	-	Very Rare	3
141.	*Cheritra freja friggia*	Common Imperial	Very Rare	3
142.	*Chilades pandava pandava*	Cycad Blue	Common	2
143.	*Deudorix epijarbas cinnabarus*	Cornelian	Rare	3
144.	*Drupadia ravindra moorei*	Common Posy	Common	3
145.	*Drupadia rufotaenia rufotaenia*[*18]	-	Very Rare	3
146.	*Drupadia theda thesmia*	Dark Posy	Very Rare	3
147.	*Eooxylides tharis distanti*	Branded Imperial	Very Common	3
148.	*Euchrypsos cnejus cnejus*	Gram Blue	Common	3
149.	*Everes lacturnus rileyi*	Indian Cupid	Very Rare	1
150.	*Flos anniella anniella*	-	Very Rare	3
151.	*Flos apidanus saturatus*	-	Rare	3
152.	*Flos diardi capeta*	-	Rare	3
153.	*Flos fulgida singhapura*	-	Rare	3
154.	*Horaga syrinx maenala*[*19]	-	Very Rare	4
155.	*Hypolycaena erylus teatus*	Common Tit	Common	4
156.	*Hypolycaena thecloides thecloides*	-	Very Rare	4
157.	*Ionolyce helicon merguiana*	Pointed Line Blue	Common	3
158.	***Iraota distanti distanti***[*20]	-	Very Rare	3
159.	*Iraota rochana boswelliana*	-	Very Rare	4
160.	*Jacoona anasuja anasuja*[*21]	-	Very Rare	3
161.	*Jamides bochus nabonassar*[*22]	-	Very Rare	3
162.	*Jamides caeruleus caeruleus*	Sky Blue	Rare	3
163.	*Jamides celeno aelianus*	Common Caerulean	Common	4
164.	*Lampides boeticus*	Pea Blue	Rare	3
165.	*Loxura atymnus fuconius*	Yamfly	Rare	3
166.	***Megisba malaya sikkima***	-	Very Rare	3
167.	*Nacaduba berenice icena*	Rounded 6-Line Blue	Rare	3
168.	*Nacaduba beroe neon*	-	Rare	3
169.	*Neocheritra amrita amrita*	Grand Imperial	Very Rare	3
170.	*Neopithecops zalmora zalmora*	-	Very Rare	3
171.	*Prosotas nora superdates*	-	Common	4
172.	*Rapala dieneces dieneces*[*23]	-	Very Rare	3
173.	*Rapala domitia domitia*	-	Rare	3
174.	*Rapala iarbus iarbus*	Common Red Flash	Rare	3

No.	Species	Common Name	Status	Habitat
175.	*Rapala manea chozeba*	-	Very Rare	3
176.	*Rapala suffusa barthema*	-	Very Rare	3
177.	*Rapala varuna orseis*	-	Rare	3
178.	*Remelana jangala travana*[*24]	Chocolate Royal	Very Rare	3
179.	*Semanga superba deliciosa*	-	Rare	3
180.	***Sinthusa nakasa amba***	-	Rare	3
181.	*Spindasis lohita senama*	Long Banded Silverline	Very Rare	3
182.	*Spindasis syama terana*	Club/Black-Banded Silverline	Very Rare	3
183.	*Surendra vivarna amisena*	Acacia Blue	Rare	3
184.	*Tajuria cippus maxentius*	Peacock Royal	Rare	4
185.	*Virachola kessuma deliochus*[*25]	-	Very Rare	3
186.	*Zeltus amasa maximinianus*	Fluffy Tit	Rare	3
187.	*Zizina otis lampa*	Lesser Grass Blue	Very Common	2
188.	*Zizula hylax pygmaea*	-	Rare	1
	Ancema blanka blanka	-	Extinct	
	Arhopala achelous achelous	-	Extinct	
	Arhopala agrata agrata	de Niceville's Dull Oakblue	Extinct	
	Arhopala alitaeus pardenas	-	Extinct	
	Arhopala allata pandora	-	Extinct	
	Arhopala ariel	-	Extinct	
	Arhopala avathina avathina	-	Extinct	
	Arhopala barami penanga	-	Extinct	
	Arhopala corinda acestes	-	Extinct	
	Arhopala delta	-	Extinct	
	Arhopala democritus lycaenaria	-	Extinct	
	Arhopala eumolphus maxwelli	Green Oakblue	Extinct	
	Arhopala fulla intaca	-	Extinct	
	Arhopala hypomuta hypomuta	-	Extinct	
	Arhopala inornata inornata	-	Extinct	
	Arhopala lurida	-	Extinct	
	Arhopala metamuta metamuta	-	Extinct	
	Arhopala milleri	-	Extinct	
	Arhopala moorei busa	-	Extinct	
	Arhopala muta maranda	-	Extinct	
	Arhopala normani	-	Extinct	
	Arhopala phanda phanda	-	Extinct	
	Arhopala silhetensis adorea	-	Extinct	
	Arhopala sublustris ridleyi	-	Extinct	
	Arhopala wildeyana wildeyana	-	Extinct	
	Bindahara phocides phocides	-	Extinct	
	Bullis buto cowani	-	Extinct	
	Catapaecilma major emas	-	Extinct	
	Deudorix elioti	-	Extinct	
	Deudorix staudingeri	-	Extinct	

No.	Species	Common Name	Status	Habitat
	Drina cowani	-	Extinct	
	Eliotia jalindra burbona	-	Extinct	
	Horaga albimacula malaya	-	Extinct	
	Horaga chalcedonyx malaya	-	Extinct	
	Horaga onyx sardonyx	-	Extinct	
	Iraota timoleon wickii	-	Extinct	
	Jamides abdul abdul	-	Extinct	
	Jamides alecto ageladas	-	Extinct	
	Jamides elpis pseudelpis	-	Extinct	
	Jamides philatus subditus	-	Extinct	
	Jamides pura pura	-	Extinct	
	Manto hypoleuca terana	-	Extinct	
	Mantoides gama gama	-	Extinct	
	Nacaduba augusta kerriana	-	Extinct	
	Nacaduba calauria malayica	-	Extinct	
	Nacaduba hermus swatipa	-	Extinct	
	Nacaduba kurava nemana	-	Extinct	
	Nacaduba pactolus odon	-	Extinct	
	Nacaduba pavana singapura	-	Extinct	
	Nacaduba pendleburyi pendleburyi	-	Extinct	
	Nacaduba russelli	-	Extinct	
	Nacaduba sanaya elioti	-	Extinct	
	Nacaduba subperusia lysa	-	Extinct	
	Pratapa deva relata	White Royal	Extinct	
	Pratapa icetoides calculis	-	Extinct	
	Prosotas dubiosa lumpura	-	Extinct	
	Pseudotajuria donatana donatana	-	Extinct	
	Purlisa gigantea gigantea	-	Extinct	
	Rapala abnormis abnormis	-	Extinct	
	Rapala cowani	-	Extinct	
	Rapala damona	-	Extinct	
	Rapala pheretima sequeira	-	Extinct	
	Tajuria deudorix ingeni	-	Extinct	
	Tajuria dominus dominus	-	Extinct	
	Tajuria mantra mantra	-	Extinct	
	Una usta usta	Singleton	Extinct	
	Virachola subguttata malaya	-	Extinct	
	Zizeeria karsandra	Dark Grass Blue	Extinct	
	Family **HESPERIIDAE** — Subfamily **COELIADINAE**			
189.	*Badamia exclamationis*	-	Very Rare	3
190.	*Bibasis etelka*[*26]	-	Very Rare	3
191.	*Bibasis harisa consobrina*	Orange Awlet	Very Rare	3
192.	*Hasora badra badra*	Common Awl	Rare	3
193.	*Hasora chromus chromus*	-	Very Rare	3
194.	*Hasora schoenherr chuza*[*27]	Yellow Banded Awl	Very Rare	3
195.	*Hasora taminatus malayana*	-	Rare	2

No.	Species	Common Name	Status	Habitat
196.	*Hasora vitta vitta*	Plain Banded Awl	Rare	3
	Choaspes subcaudatus crawfurdi	-	Extinct	
	Hasora lizetta	-	Extinct	
	Family **HESPERIIDAE** — Subfamily **PYRGINAE**			
197.	*Gerosis limax dirae*[*28]	-	Very Rare	3
198.	***Gerosis phisara phisara***[*29]	-	Very Rare	3
199.	*Odina hieroglyphica ortina*	-	Very Rare	3
200.	*Odontoptilum angulatum angulatum*[*30]	-	Very Rare	3
201.	*Tagiades calligana*	-	Rare	3
202.	*Tagiades gana gana*	Large Snow Flat	Rare	3
203.	*Tagiades japetus atticus*	Common Snow Flat	Rare	3
204.	***Tagiades ultra***	-	Very Rare	3
205.	***Tapena thwaitesi bornea***[*31]	-	Very Rare	3
	Celaenorrhinus asmara asmara	-	Extinct	
	Gerosis tristis	-	Extinct	
	Family **HESPERIIDAE** — Subfamily **HESPERIINAE**			
206.	*Ampittia dioscorides camertes*[*32]	Bush Hopper	Rare	3
207.	*Ancistroides nigrita maura*	Chocolate Demon	Rare	3
208.	*Caltoris cormasa*	-	Rare	3
209.	*Caltoris philippina philippina*	-	Common	3
210.	*Eetion elia*	-	Rare	3
211.	*Erionota acroleuca apicalis*[*33]	-	Very Rare	3
212.	*Erionota thrax thrax*	Banana Skipper	Rare	4
213.	*Erionota torus*	-	Rare	4
214.	*Gangara thyrsis thyrsis*[*34]	Giant Redeye	Very Rare	3
215.	*Halpe ormenes vilasina*	-	Very Rare	3
216.	*Hidari irava*	Coconut Skipper	Rare	4
217.	*Hyarotis adrastus praba*	-	Very Rare	3
218.	*Iambrix salsala salsala*	Chestnut Bob	Rare	3
219.	*Iambrix stellifer*	Starry Bob	Very Rare	3
220.	*Matapa aria*	Common Redeye	Very Rare	3
221.	*Notocrypta paralysos varians*	Banded Demon	Rare	3
222.	*Oriens gola pseudolus*	Common Dartlet	Very Rare	3
223.	*Pelopidas mathias mathias*	Small Branded Swift	Common	4
224.	*Plastingia naga*	-	Rare	3
225.	*Plastingia pellonia*[*35]	-	Very Rare	3
226.	*Polytremis lubricans lubricans*	Contiguous Swift	Common	4
227.	*Potanthus omaha omaha*	Lesser Dart	Common	4
228.	*Pyroneura latoia latoia*	Yellow Veined Lancer	Common	3
229.	*Quedara monteithi monteithi*[*36]	-	Very Rare	3
230.	***Suastus everyx everyx***[*37]	-	Very Rare	3
231.	***Suastus gremius gremius***	-	Rare	2
232.	***Taractrocera ardonia lamia***	-	Very Rare	3
233.	*Telicota besta bina*	-	Common	4
234.	*Udaspes folus*	Grass Demon	Rare	2

No.	Species	Common Name	Status	Habitat
235.	*Unkana ambasa batara*	Hoary Palmer	Very Rare	3
236.	***Zela zenon****[38]	-	Very Rare	3
	Astictopterus jama jama	Forest Hopper	Extinct	
	Baoris farri farri	-	Extinct	
	Baoris oceia	Paintbrush Swift	Extinct	
	Borbo cinnara	Formosan Swift	Extinct	
	Caltoris malaya	-	Extinct	
	Cephrenes acalle niasicus	-	Extinct	
	Gangara lebadea lebadea	-	Extinct	
	Idmon distanti	-	Extinct	
	Idmon obliquans obliquans	Small Red Bob	Extinct	
	Notocrypta clavata clavata	-	Extinct	
	Parnara bada bada	-	Extinct	
	Pelopidas agna agna	-	Extinct	
	Pemara pugnans pugnans	Pugnacious Lancer	Extinct	
	Potanthus confucius dushta	-	Extinct	
	Potanthus heraerus serina	-	Extinct	
	Potanthus juno juno	-	Extinct	
	Potanthus trachala tytleri	-	Extinct	
	Psolos fuligo fuligo	The Coon	Extinct	
	Telicota augias augias	Palm Dart	Extinct	
	Telicota colon stinga	-	Extinct	
	Zela cowani	-	Extinct	
	Zographetus doxus	-	Extinct	
	Zographetus ogygia ogygia	-	Extinct	
	Zographetus rama	-	Extinct	

Compiled by Khew Sin Khoon, 1 September 1998.

- New records for Singapore are printed in bold.
- Species identified in the genus *Arhopala* are tentative and subject to further verification.
- The extinct species have either not been seen in recent years or are believed to be extinct. However, it is still possible that some of these may turn up in continuing surveys.

[1] Very seasonal. No physical records taken in recent years.
[2] Record verified by a single physical specimen taken in the Mandai area.
[3] Very local in distribution. Found mainly in the Sembawang area.
[4] Species recorded by a single physical specimen taken at Nee Soon Pipeline.
[5] Very local in distribution. Observed only on Pulau Ubin.
[6] Species recorded by a single photographed specimen at Night Safari Zoo.
[7] Species recorded by a single physical specimen taken in Lower Peirce Reservoir area.
[8] Species recorded in early 90s. None observed in recent years.
[9] Not seen in recent years, except for one physical specimen taken on the Gangsa Track, Chestnut Ave.
[10] Two unconfirmed sightings at Upper Seletar Reservoir Park.
[11] Not seen in recent years, except one physical specimen taken in the Mandai area.

[12] Very localised distribution in the Mandai area.
[13] All specimens taken on the Gangsa Track, Chestnut Ave.
[14] Very local in distribution. Records mainly from Sungei Buloh Nature Park.
[15] Species recorded from a single physical specimen taken on the Island Club Track.
[16] Species recorded from a single physical specimen taken in the MacRitchie area.
[17] Species recorded from two physical specimens taken at Pulau Ubin and Khatib Bongsu.
[18] Species recorded from a single physical specimen taken on the Island Club Track.
[19] Three unconfirmed sightings in Feb 98. No physical specimens taken.
[20] Species recorded from a single physical specimen taken in the MacRitchie area.
[21] Species recorded from a single physical specimen taken in the Mandai area.
[22] Species recorded from a single physical specimen taken on the Gangsa Track.
[23] Species recorded from a single physical specimen taken on the Gangsa Track.
[24] Species recorded from a single physical specimen taken in the Upper Seletar Reservoir Park.
[25] Species recorded from a single physical specimen taken on the Gangsa Track.
[26] Species recorded from a single physical specimen taken at Nee Soon Pipeline.
[27] Species recorded from a single physical specimen taken on the Island Club Track.
[28] Species recorded from a single physical specimen taken on the Island Club Track.
[29] Species recorded from a single physical specimen taken at Upper Peirce Reservoir.
[30] Species recorded from a single physical specimen taken at Nee Soon Pipeline.
[31] Species recorded from a single physical specimen taken in the Sime Road area.
[32] Very local. Found only on the Water's Edge Path, Chestnut Ave area.
[33] Species recorded from a single physical specimen taken in the Upper Seletar Reservoir Park.
[34] Unconfirmed observation on the Island Club Track.
[35] Species recorded from a single physical specimen taken at Nee Soon Pipeline.
[36] Species recorded from two physical specimens taken in the Upper Seletar Reservoir Park.
[37] Species recorded from a single physical specimen taken at Upper Peirce Reservoir.
[38] Species recorded by a single physical specimen taken in the Upper Seletar Reservoir Park.

Plate 1a Khew Sin Khoon

Plate 1b Khew Sin Khoon

Plate 1c Khew Sin Khoon

Plate 1d Khew Sin Khoon

Plate 1e Khew Sin Khoon

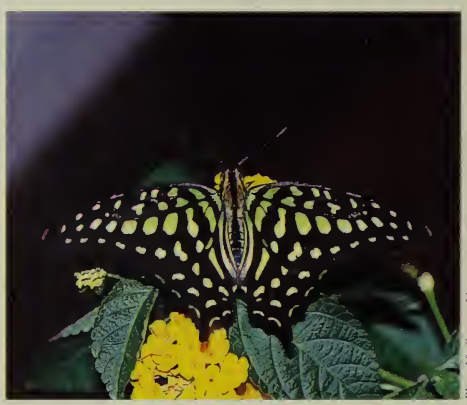

Plate 1f Steven Neo

Plate 1. Family Papilionidae. a. The Great Mormon *(Papilio memnon agenor) female form-esperi* is the commonest of the four forms found in Singapore. **b.** The Common Mormon *(Papilio polytes romulus)* - recently hatched males drying their wings. **c.** The Banded Swallowtail *(Papilio demolion demolion)* is a threatened species. **d.** The Common Birdwing *(Troides helena cerberus)*, being very dependent on its caterpillar host plant, *Aristolochia tagala*, is extremely vulnerable to extinction. **e.** The Five Bar Swordtail *(Pathysa antiphates itamputi)* is a relatively rare and forest-dependent species. **f.** The Tailed Green Jay *(Graphium agamemnon agamemnon)* can be found in the reserves and housing estates.

Plate 2a Khew Sin Khoon

Plate 2b Steven Neo

Plate 2c Khew Sin Khoon

Plate 2d Khew Sin Khoon

Plate 2. Family Nymphalidae—Subfamily Danainae (a—b) and Subfamily Satyrinae (c—d). **a.** The Common Tree Nymph *(Idea stolli logani)* is a forest-dependent species which floats among tree tops. **b.** The Plain Tiger *(Danaus chrysippus chrysippus)* is extremely rare and sightings are limited to northen part of the island. **c.** The Tawny Palmfly *(Elymnias panthera panthera)* is a forest-dependent species which feeds on palms. **d.** The Malayan Bush Brown *(Mycalesis fusca fusca)* is a forest-dependent species which is usually seen singly amongst low-growing shrubs and grasses.


Plate 3a Khew Sin Khoon


Plate 3b Khew Sin Khoon


Plate 3c Khew Sin Khoon


Plate 3d Khew Sin Khoon

Plate 3. Family Nymphalidae—Subfamily Nymphalinae (a—c) and Subfamily Charaxinae (d). a. This rare *Athyma asura idita* is a forest-dependent species. **b.** This extremely rare *Euthalia adonia pinwilli* is most often seen on the western banks of the Upper Peirce Reservoir. **c.** *Lexias dirtea merguia* is a rare forest-dependent species. **d.** *Polyura hebe plautus*, a subspecies thought to occur only in Singapore, and southern Johore.

Plate 4a Steven Neo

Plate 4b Khew Sin Khoon

Plate 4c Khew Sin Khoon

Plate 4d Khew Sin Khoon

Plate 4. Family Lycaenidae—Subfamily Riodininae (a—b) and Subfamily Lycaeninae (c—d). a. *Abisara geza niya* is a rare forest-dependent species. **b.** The Lesser Harlequin *(Laxita thuisto thuisto)* is a rare forest-dependent species. **c.** *Arhopala abseus abseus* is more common here than in Malaysia. **d.** The forest-dependent Common Posy *(Drupadia ravindra moorei)* is found throughout the Nature Reserves.

Plate 5a Steven Neo

Plate 5b Steven Neo

Plate 5c Steven Neo

Plate 5d Khew Sin Khoon

Plate 5e Khew Sin Khoon

Plate 5. Family Lycaenidae—Subfamily Lycaeninae (a—c), Family Hesperiidae—Subfamily Pyrginae (d) and Subfamily Coeliadinae (e). a. The Common Tit - Caterpillar stage. **b.** The Common Tit - Pupa stage. **c.** The Common Tit *(Hypolycaena erylus teatus)*. **d.** *Tagiades calligana*, a forest-dependent species which is usually seen singly. **e.** The rare Orange Awlet *(Bibasis harisa consobrina)* is bred on *Arthrophyllum diversifolium* found in the Nature Reserves.

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Stick and Leaf Insect (Phasmida: Insecta) Biodiversity in the Nature Reserves of Singapore

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Abstract

Forty-one species of phasmids found in Singapore extant as well as extinct are listed and aspects of their conservation discussed. Eleven species are still relatively common and are widely distributed especially within the Central Catchment Nature Reserve. Eleven species exist in only very isolated pockets within the Central Catchment Nature Reserve. One species has been found only in the Punggol area. A further ten species are very rare and in almost a decade of studying these insects only one or two specimens have been found in Singapore. An additional eight species have not been seen or recorded for at least 30 years and are best described as extinct in Singapore.

Introduction

Stick and Leaf Insects (order Phasmida) are common but little known insects of tropical and subtropical forests. Indeed, South-East Asia has a large number of species. Most if not all species have an uncanny ability to "disappear" into their surroundings by mimicking sticks and leaves thus earning them their names Phasmida and Spectres, both meaning 'ghost-like'. Phasmids are food plant specific and all species refuse to eat unless the plants offered are acceptable to that particular species. Most species will take only a few species of naturally occurring plants. Similar species may eat similar plants while species from different genera eat totally different plants. In the wild, phasmids are usually located on or near their food plants. This may, therefore, make phasmids a good indicator of forest health. A wide variety of phasmids is an indicator of the presence of a wide variety of plant species.

The order Phasmida is divided into three suborders and six families. The suborder Timematodea consists of one family of small insects with three segmented tarsi and is found only in North and Central America. All other phasmids are therefore divided into one of the other two suborders. The suborder Areolatae consists of insects where the middle and hind tibiae have a sunken triangular region or areola on the underside of the apices. The suborder Anareolatae is made up of insects without this sunken areola. The suborder Areolatae consists of the families Bacillidae,

Pseudophasmatidae and the Phyllidae. The suborder Anareolatae consists of the families Heteronemiidae and the Phasmatidae.

History and Methods

Prior to the present survey, reports of phasmids from Singapore were scanty and limited to occasional and infrequent accounts (Westwood, 1859; Brunner & Redtenbacher, 1906–08; Ridley, 1894). During the course of this survey, several reports were published including new records and new species (Seow-Choen, 1993a-e, 1995a-d, 1996a-b, 1997a-b; Seow-Choen & Brock, 1996; Seow-Choen *et al.,* 1994a-d; Seow-Choen *et al.,* 1994e; Tay & Seow-Choen, 1996, Seow-Choen & Seow-En, 1994; Seow-Choen *et al.*, 1996 & Brock, 1995)

Details of records from Singapore were based on field observations by the author, friends and colleagues as well as extensive searches of the literature and examination of museum collections. The author started working on Singapore phasmids in 1990. Full details on synonyms and museum records may be found in Brock (1999). Field work consisted mainly of meticulous searching after dark of bushes along paths within the Nature Reserves. These insects are nocturnal and daytime searching is futile. Night-time searching with a powerful hand torch gives the best results. Searches are normally made from ground to a level of about 3 m from ground level. Searches higher up were not made as capture of insects at such levels would have been impossible. It is possible that many insects that are considered rare are present at the top of the canopy but these are impossible to assess at the present time by the current methods employed by the author. Torch lighting obviously allows only for capture of individual insects one at a time and is time consuming and labour intensive.

Phasmid ecology, including food plants and aspects of their life cycle, was also investigated as the author is successful in rearing many of the local species.

Results

The Phasmida classification of Bradley and Galil (1977) lists three suborders, six families and 17 subfamilies. In our survey of Singapore forests, we have found representatives from two suborders, five families and six subfamilies (Table 1). Altogether 41 species have been found or been recorded in the past from Singapore. In the course of our research into Singapore's Phasmids, 18 new records for Singapore were established, numerous synonyms cleared up and three undescribed species found. Two

species (*Abrosoma xiuyuae* and *Asceles singapura*) have since been described. One species is still undescribed and could possibly represent a new genus.

Table 1. Checklist of Phasmids in Singapore and their status.
(C=common, I= isolated pockets, R= rare, E=extinct)

No.	Species	Status
	Suborder **AREOLATAE**	
	Family **BACILLIDAE** — Subfamily **HETEROPTERYGINAE**	
1.	*Datames oileus* (Westwood) 1859	C
2.	*Datames mouhotii* (Bates) 1865	I
3.	*Heteropteryx dilatata* (Parkinson) 1798	E
4.	*Planispectrum bengalensis* (Redtenbacher)1906	R
	Family **PSEUDOPHASMATIDAE** — Subfanily **ASCHIPHASMATINAE**	
5.	*Abrosoma xiuyuae* Brock & Seow-Choen 1999	C
6.	*Presbistus peleus* (Gray) 1835	C
7.	*Presbistus flavicornis* (de Haan 1842)	E
	Family **PHYLLIDAE**	
8.	*Phyllium bioculatum* Gray 1832	R
9.	*Phyllium siccifolium* (Linnaeus) 1758	R
	Suborder **ANAREOLATAE**	
	Family **HETERONEMIIDAE** — Subfamily **NECROSCIINAE**	
10.	*Acacus sarawacus* (Westwood) 1859	I
11.	*Asceles malaccae* (Saussure)1868	C
12.	*Asceles larunda* (Westwood) 1859	C
13.	*Asceles singapura* Seow-Choen & Brock 1999	I
14.	*Calvisia sangarius* (Westwood) 1859	E
15.	*Diacanthoidea diacanthos* (de Haan) 1842	R
16.	*Diesbachia tamyris* (westwood) 1859	I
17.	*Gargantuoidea phaetusa*(Westwood) 1859	E
18.	*Gargantuoidea triumphalis* Redtenbacher 1908	R
19.	*Lopaphus brachypterus* (de Haan) 1842	R
20.	*Lopaphus iolas* (Westwood) 1859	I
21.	*Marmessoidea rosea* (Fabricius) 1793	E
22.	*Necroscia punctata* (Gray) 1835	I
23.	*Necroscia affinis* (Gray) 1835	C
24.	*Necroscia roseipennis* Audinet-Serville 1838	C
25.	*Necroscia westwoodi* Kirby 1904	I
26.	*Necroscia inflata* (Redtenbacher) 1908	C
27.	*Phaenopharos struthioneus* (Westwood) 1859	E
28.	*Sipyloidea sipylus* (Westwood) 1859	I
29.	*Sipyloidea meneptolemus* (Westwood) 1859	R

No.	Species	Status
30.	*Sosibia esacus* (Westwood) 1859	I
31.	*Sosibia solida* Redtenbacher 1908	I
32.	*Baculofractum insignis* (Brunner von Wattenwyl) 1907	R
33.	Undescribed species	R
	Family **HETERONEMIIDAE** — Subfamily **LONCHODINAE**	
34.	*Carausius nodosus* (de Haan) 1842	I
35.	*Lonchodes brevipes* Gray 1835	C
36.	*Lonchodes geniculatus* Gray 1835	C
37.	*Prisomera malaya* (Stål) 1875	C
	Family **HETERONEMIIDAE** — Subfamily **HETERONEMIINAE**	
38.	*Bactricia ridleyi* Kirby 1904	E
	Family **PHASMATIDAE** — Subfamily **PHASMATINAE**	
39.	*Baculum nematodes* (de Haan) 1842	I
40.	*Eurycnema versirubra* (Audinet-Serville) 1838	E
41.	*Phobaeticus serratipes* (Gray) 1835	R

All the living phasmids located by the author were found in the Central Catchment Nature Reserve and its surrounding fringe areas such as the forest within the Singapore Island Country Club locality. The full list of phasmid food plants is not discussed here as it has been published (Tay & Seow-Choen, 1996).

Eleven species are still relatively common and are widely distributed especially in the Central Nature Reserve Areas. These are *Datames oileus* (Plate 1a), *Presbistus peleus, Abrosoma xiuyuae, Asceles malaccae, A. larunda* (Plate 1b), *Necroscia affinis* (Plate 1c–e), *N. roseipennis* (Plate 2a–b), *N. inflata, Lonchodes brevipes* (Plate 2c), *L. geniculatus* (Plate 2d) and *Prisomera malaya*. All these species are common because their food plants are very common within the Nature Reserves.

Datames oileus is a small ground or low-lying species that feeds mainly on *Curculigo* spp. (Hydrophyllaceae), palms, and various species of aroids. This species is therefore widely distributed in the Nature Reserve and is especially common in Bukit Timah Nature Reserve and the trail leading from Singapore Island Country Club to MacRitchie Reservoir (S-M trail). *Prebistus peleus* feeds only on *Leea indica* (Leeaceae), a very common shrub within the Nature Reserves and its fringes, *A. xiuyuae* is widespread and its feeding marks are found on every *Pternandra echinata* (Melastomataceae) that I have encountered. Strangely this phasmid was undescribed before this survey began. *Asceles malaccae* and *A. larunda* are very common flying insects that feed mainly on the various *Macaranga* species. These are common along the S-M trail as well as in Upper Pierce

Reservoir Park. *Necroscia affinis* and *N. roseipennis* are also commonly seen. These very pretty insects are beautifully coloured. *Necroscia affinis* occurs in various shades of green, yellow, brown and even red, all with yellow spots. *Necroscia roseipennis* possesses bright rose coloured wings. They feed on *Cinnamomum iners* (Lauraceae) and *N. roseipennis* may also be found on *Gomphandra quadrifida* (Icacinaceae). *Necroscia roseipennis* and *N. affinis* are common at the S-M trail, and may also be found along Rifle Range Road trail. Unfortunately these insects have not spread to roadside cinammon trees as the dryness and heat make the sides of highways and roads very unsuitable for these insects for which high humidity is essential for their survival. *Necroscia inflata* is another very common insect found on the various *Uncaria* species and on *Mussaenda glabra* in the Nature Reserves. It is very common at Rifle Range Road, Upper Pierce Road and along the S-M trail. *Lonchodes brevipes, L. geniculatus* and *P. malaya* are also widespread species within the Nature Reserves. Of these three species, *L. geniculatus* is perhaps the most common, especially along the S-M Trail. It feeds on a wide variety of plants, including various *Uncaria* species, *Ilex macrophylla* (Aquifoliaceae) and *Psychotria rostrata* (Rubiaceae). *Prisomera malaya* feeds on various low-growing ferns and it is also commonly encountered along the S-M trail and on Bukit Timah Hill. *Lonchodes brevipes* feeds on these plants as well as *Grewia acuminata* (Tiliaceae) and introduced species such as *Acacia auriculiformis* (Leguminosae) and *Hibiscus rosa-sinensis* (Malvaceae). It is widespread but not as commonly seen as the other two species just mentioned. *Lonchodes brevipes* was found on Pulau Ubin as well as in Labrador Park.

Unfortunately, 11 species exist in only very isolated pockets within the Central Catchment Nature Reserve. These are *Datames mouhotii, Acacus sarawacus* (Plate 3a–b), *Asceles singapura* (Plate 3c–d), *Diesbachia tamyris*, *Lopaphus iolas* (Plate 3e), *Necroscia punctata* (Plate 4a–b), *N. westwoodi*, *Sosibia esacus, S. solida* (Plate 4c), *Carausius nodosus* (Plate 4d) and *Baculum nematodes* (Plate 4e). Although *D. mouhotii* feeds on the same plants as *D. oileus*, it is found only in a small patch of forest in Upper Seletar Reservoir Park. The reason it has not spread like *D. oileus* is not immediately obvious. Perhaps it is because the species is less prolific or hardy as it is probably a parthenogenetic species. No male has ever been found. *Acacus sarawacus* exists only in one spot along the S-M trail. It is a very difficult species to keep alive in captivity and requires high humidity at all times. It feeds on *Lithocarpus ewyckii* in the wild and *Psidium guajava* when in captivity. *Asceles singapura* also feeds on *Macaranga*, especially *Macaranga gigantea,* but its range seems to be confined to Upper Pierce and the S-M trail. *Diesbachia tamyris* and *C. nodosus* are found in the same general area in MacRitchie Reservoir on the trail to the Shinto Shrine.

Carausius nodosus is always found on *Rourea mimosoides* (Connaraceae) along this trail. The wild food plant of *D. tamyris* is not known. *Lopaphus iolas* is only found near the freshwater swamp forest area within the Nature Reserves, although it feeds on a wide variety of plants. *Necroscia punctata* and *N. westwoodi* may be found on Bukit Timah Hill and occasionally along the S-M trail. The former feeds on *Cinnamomum iners* (Lauraceae) and the latter on *Psychotria malayana* (Rubiaceae). Again the reason for the isolation of *N. punctata* is not obvious as *Cinnamomum iners* is a common tree. *Necroscia punctata* may also be found along the Upper Pierce Road. *Sosibia esacus* and *S. solida* are both limited to areas where their food plant grows. *Sosibia esacus* may be found along Upper Pierce Road, and Bukit Timah Hill whereas *S. solida* is found along the S-M trail. *Sosibia esacus* feeds on *Salacia macrophylla* and *Ixonanthes reticulata.* The food plant of *S. solida* is still unidentified. *Baculofractum nematodes* is a very long species in the female reaching up to 190 mm. It was found on *Grewia acuminata* (Tiliaceae) along Upper Pierce Road and near the freshwater swamp forest area.

Sipyloidea sipylus has been found only in the Punggol area feeding on cultivated guava. It had not been encountered within the Nature Reserves.

A further ten species are very rare and in almost a decade of studying these insects, only one or two specimens have been found in Singapore. These are *Planispectrum bengalensis, Phyllium bioculatum, P. siccifolium* (Plate 5a), *Diacanthoidea diacanthos* (Plate 5b), *Gargantuoidea triumphalis, Lopaphus brachypterus* (Plate 5c–d), *Sipyloidea meneptolemus, Baculofractum insignis* (Plate 6a), *Phobaeticus serratipes* and an undescribed species of Necrosciinae (Plate 6b). *Planispectrum bengalensis* is very tiny and is ground dwelling and this may explain its rarity. *Phyllium* species are very difficult to find as they are tree top dwellers. The winged phasmids; *D. diacanthos, G. triumphalis, L. brachypterus, S. meneptolemus* and *B. insignis* are very specialised feeders and this may explain their rarity. The female *B. insignis* is not winged but is a very fussy feeder nonetheless. *Phobaeticus serratipes* is a very common insect in West Malaysia and feeds on a wide variety of plants including *Mangifera indica*, *Macaranga* spp., *Uncaria* spp. and many others, which explains its frequency. In Singapore, however, it is very rare inspite of the presence of its food plants. Perhaps its long length has to do with its rarity as it may make the insect more readily detectable by both human and animal predators. The longest female on record measured 555 mm from tip of front claw to tip of the hind claw. The undescribed species is currently being researched but its rarity may make work on this species very difficult.

An additional eight species have not been seen or recorded for at

least 30 years and are best described as extinct in Singapore. These are *Heteropteryx dilatata, Presbistus flavicornis, Calvisia sangarius* (Plate 6c), *Gargantuiodea phaetusa, Marmessoidea rosea, Phaenopharos sthruthioneus* (Plate 6d), *Bactricia ridleyi* and *Eurycnema versirubra. Heteropteryx dilatata* and *E. versirubra* are large impressive species and may have been destroyed by farmers clearing land in the early days. These insects were also kept in the past by Malays and Chinese as their droppings were used for a variety of ailments including diarrhoea and as an aphrodisiac. Perhaps they were overcollected for this purpose. The other insects are probably all very specialised feeders and occurred only in isolated pockets where their food plants were found. Entire populations may have been destroyed when the original forest was cleared. *Bactricia ridleyi* is known only from the holotypic specimen found by H.N. Ridley in the Singapore Botanic Gardens.

Discussion

Singapore has only about 2675 ha of forest left which includes reservoir areas in the Central Catchment Nature Reserve as well as 164 ha of forest at Bukit Timah Nature Reserve (National Parks Board, *pers. comm.*). A well thought-out and planned conservation programme for these forested areas is of utmost importance, if Singapore's remaining flora and fauna are to survive.

Phasmids are phytophagous and indeed very particular about the species of leaves they eat. Many species of phasmids will only feed on a very few species of plants. Destruction of these plants will therefore result in the elimination of food plant dependent insect species. Many species, which have particularly specific food plant requirements, are therefore either extinct, at serious risk of extinction or occur only in very isolated pockets where these plants may be found. In primary rain forests, many hundreds of species of plants are found and an individual of a particular species may be widely separated from the next. Destruction of our natural forest trees is an important cause of the disappearance of some of our indigenous stick-insect species as when forests are cleared stick-insect food plant are lost. The resulting effect is that the stick-insect species dependent on these food plants are eliminated and are not to be found at the cleared sites anymore.

The continual encroachment of man into the fringes of forested areas also has had very negative effects on our insect populations. The building of houses near the Nature Reserves poses a very serious problem. Many of the flying insect species including phasmids are attracted to light and many are therefore eliminated in this manner. This threat is far more damaging

than collection by insect enthusiasts. Lights from street lamps and houses probably attract and result in the death of far more insects than all insect enthusiasts can collect in their combined life times.

Combined with the building of roads and houses adjacent to the forests is mankind's general dislike for insects and his rampant use of insecticides, pesticides and herbicides. Phasmids are very sensitive insects and will not tolerate any amount of insect poison with the result that indiscriminate spraying of pesticides had eliminated most of Singapore's phytophagus insects.

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Plate 1a.


Plate 1b.


Plate 1c.


Plate 1d.


Plate 1e.

Plate 1. Some of the common and widely distributed species in the Nature Reserves. a. A mating pair of the common *Datames oileus*. These small insects feed on the Money plant (*Epipremnum aureum*, Araceae). **b.** A mating pair of the common *Asceles larunda*. All *Asceles* species are *Macaranga* feeders. **c.** A red specimen of *Necroscia affinis*. This species has several colour varieties. It may be seen along Upper Pierce Road feeding on wild cinnamon. **d.** A brown variety of *Necroscia affinis*. **e.** A mating pair of the green variety of *Necroscia affinis*.


Plate 2a.


Plate 2b.


Plate 2c.


Plate 2d.

Plate 2. Some of the common and widely distributed species in the Nature Reserves. a. A green adult female *Necroscia roseipennis*. **b.** A brown adult male *Necroscia roseipennis*. **c.** A female *Lonchodes brevipes* resting among leaves. This common species is very easily reared in captivity as it feeds on a wide variety of garden-plants including guava, hibiscus, rose and bramble. **d.** A mating pair of *Lonchodes geniculatus*. It is common in all parts of the Nature Reserve but does not feed on any common garden-plants.


Plate 3a.


Plate 3b.


Plate 3c


Plate 3d


Plate 3e

Plate 3. Species found in only isolated pockets within the Central Catchment Nature Reserve. **a.** A male *Acacus sarawacus* shows the white knees typical of the sex. This species is found only in a very small patch of forest along the MacRitchie to the Singapore Island Country Club trail. **b.** A female *Acacus sarawacus* lies very still in a state of thanatosis after being disturbed in the hope of escaping detection. **c.** A female *Asceles singapura* on *Macaranga*. This species was described recently from specimens found in Singapore. It is found along isolated pockets of forest in Upper Pierce and along the MacRitchie-Island Club trail. **d.** A nymphal *Asceles singapura*. **e.** *Lopaphus iolas* is common all over Peninsular Malaysia but is found only near the fresh water swamp forest in Singapore. This is a female adult.


Plate 4a.


Plate 4b.


Plate 4c.


Plate 4d.


Plate 4e.

Plate 4. Species found in only isolated pockets within the Central Catchment Nature Reserve. **a.** *Necroscia punctata* is a very colourful species that is occasionally encountered. This is a green variety. **b.** This is a red *Necroscia punctata.* **c.** Another view of an adult *Sosibia solida.* **d.** *Carausius nodosus* is found only in isolated pockets along the MacRitchie trail to the old Shinto Shrine. The female bears a pair of tufts on the head. Both sexes have bright red mid femurs. **e.** *Baculum nematodes* is found only along Upper Pierce Road and the fresh water swamp forest area.

Plate 5a

Plate 5b.

Plate 5c.

Plate 5d.

Plate 5. Some of the rare species encountered in the Nature Reserves. a. *Phyllium siccifolium* is another leaf insect that may be found in Singapore albeit very rarely. **b.** A male *Diacanthoidea diacanthos* is very rare. Only one specimen has ever been found in Singapore and that at Upper Pierce Road. **c.** *Lopaphus brachypterus* is a rare insect found only very occasionally. This is a male. **d.** A female *Lopaphus brachypterus* feeding on guava.


Plate 6a


Plate 6b


Plate 6c.


Plate 6d.

Plate 6. Some of the rare species encountered in the Nature Reserves (a–b). Two of the extinct species (c–d). a. *Baculofractum insignis* is very rare in Singapore and may be found only around the fresh water swamp forest. **b.** An unidentified Necrosciinae which may represent a new genus. **c.** *Calvisia sangarius*, now extinct in Singapore, is a very specialized feeder and as far as is known feeds only on a very pungent forest tree. **d.** *Phaenopharos struthioneus* is extinct in Singapore and has not been seen for many decades now.

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Semi-aquatic Bug (Heteroptera: Gerromorpha) Fauna in the Nature Reserves of Singapore

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Abstract

A total of 37 species of semiaquatic bugs were recorded from the forest during the survey of the Nature Reserves. 78% were found in the Nee Soon Swamp Forest that also has the highest percentage of the rare or threatened species on the island. Bukit Timah Nature Reserve has the lowest diversity. Three forest-dependent species, *Cylindrostethus malayensis*, *Ventidius hungerfordi* and *Esakia fernandoi* previously recorded from Singapore were not found and hence are, presumed extinct. Eight species are new records for Singapore.

Introduction

Early studies on the Singapore's freshwater bugs were scattered in some reports (van Martens, 1876; Esaki, 1926, 1930). After 1960, substantial studies on Malaysian fauna were carried out by the University of Singapore. Researchers documented a total of 15 species of Gerridae and two species of Veliidae in Singapore (Cheng, 1965; Cheng & Fernando, 1969; Fernando & Cheng, 1974). Murphy (1990) reviewed the fauna and increased the species list to 19 Gerridae, eight Veliidae, two Hydrometridae and two Mesoveliidae from freshwater habitats. However, he also failed to record three species (*Cylindrostethus malayensis, Ventidius hungerfordi* and *Esakia fernandoi*) previously recorded by Cheng and Fernando.

In view of changes in the forest habitats caused by development and other human activities in recent years, this study was conducted to provide a present-day checklist of the semiaquatic bugs (Gerromorpha) found in the forest. It is also to record the diversity and distribution of the fauna of the Bukit Timah Nature Reserve and Central Catchment Nature Reserve that are separated by the Bukit Timah Expressway.

As the true aquatic bugs (Nepomorpha) are rarely found in the forest because of the poor vegetation growth in and along streams and the lack of natural standing waters, they are not discussed in this report.

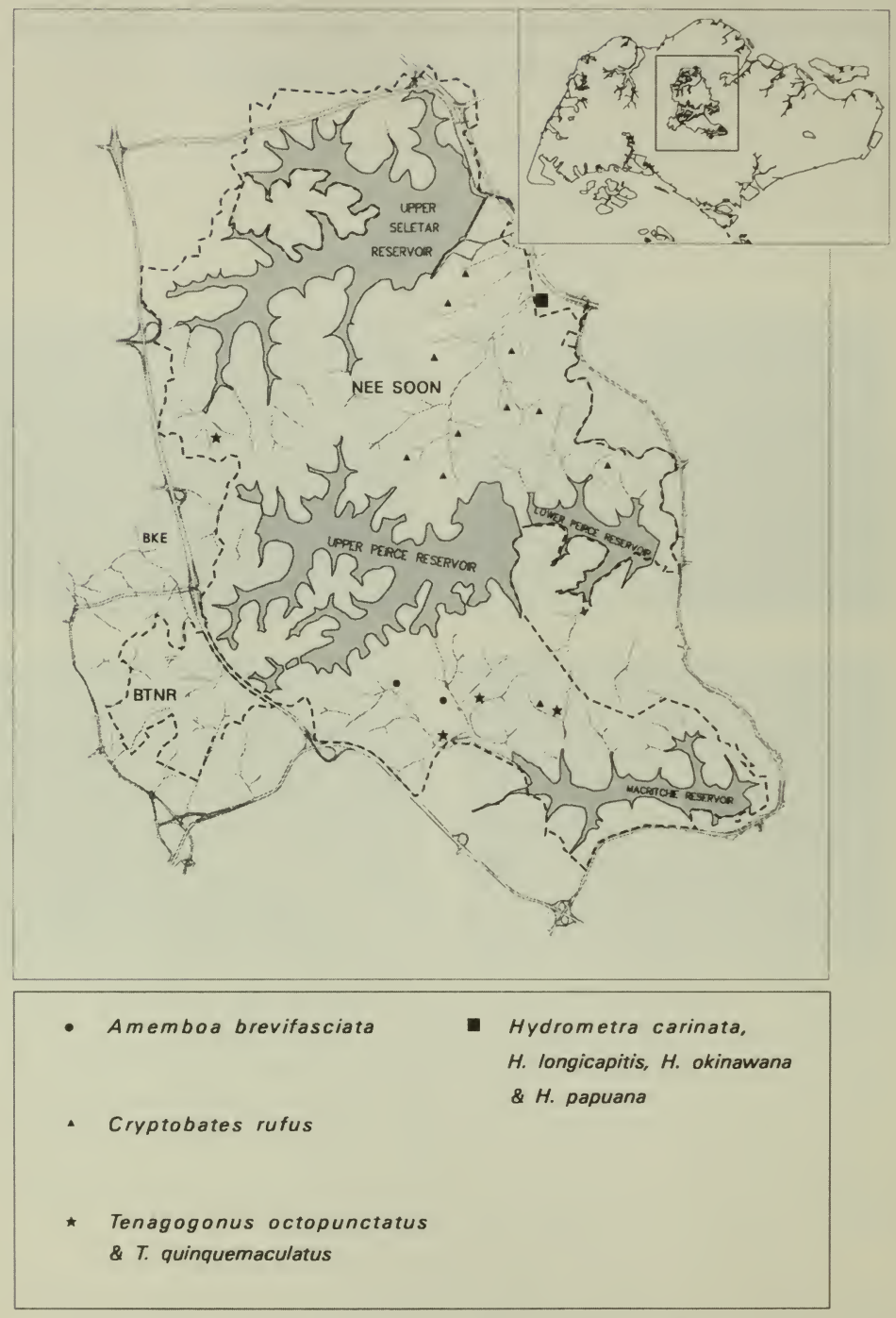

Figure 1. Distribution of some rare heteropteran bugs in the Nature Reserves. Inset shows the location of the Nature Reserves in Singapore. BTNR: Bukit Timah Nature Reserve, BKE: Bukit Timah Expressway, ------ : Boundary of Nature Reserves.

Materials and Methods

The survey area (Figure 1) covered in this study included all the water drainages found in the Central Catchment Nature Reserve and the Bukit Timah Nature Reserve from 1992 to 1995. Specimens were collected by hand nets or by hand and then either preserved in 75% alcohol or pinned dry. They were deposited in the Zoological Reference Collection of the National University of Singapore.

Results and Conclusions

A total of 37 species of semiaquatic bugs were recorded from the reserves during this survey (Table 1), with 36 species found in the Central Catchment Nature Reserve and 17 species in the Bukit Timah Nature Reserve. Of the 24 forest species, 13 are considered rare in Singapore and they are mostly distributed in the Central Catchment Nature Reserve. Eight species: *Tenagogonus octopunctatus*, *Ventidius modulatus*, *Microvelia albolineolata*, *Neoalardus typicus*, *Hydrometra carinata*, *H. longicapitis*, *H. okinawana* and *H. papuana* were recorded from Singapore for the first time. Several other recently published records were also based on the materials collected in the Nature Reserves notably, *Cryptobates rufus*, *Rhagovelia singaporensis* and *R. rudischuhi* (Polhemus & Polhemus, 1995a; Yang & Polhemus, 1994).

Table 1. Distribution of Gerromorphan bugs in the Singapore Nature Reserves. S : Seletar; M : MacRitichie; N : Nee Soon; J : Jungle Fall Valley; P : Peripheral (F : forest species; R : rare, restricted distribution; C : common; U : uncommon; 1 : moderate/fast flowing water; 2 : slow flowing water; 3 : swamp forest; 4 : pool and puddle; 5 : margin of water or bank; * : new record; + : present; - : absent.)

Species	Status	Habitat	Central Catchment			Bukit Timah	
			S	M	N	J	P
Family **GERRIDAE**							
1. *Amemboa brevifasciata* Miyamoto, 1967	FR	2,5	-	+	-	-	-
2. *Amemboa riparia* Polhemus & Andersen, 1984	FU	2,5	+	+	+	-	+
3. *Aquarius adelaides* (Dohrn, 1860)	U	4	+	+	-	-	-
4. *Cryptobates rufus* J & D Polhemus, 1995	FR	3	-	+	+	-	-
5. *Limnogonus fossarum* (Fabricius, 1775)	U	4	+	+	+	-	+
6. *Metrocoris tenuicornis* Esaki, 1926	FC	2	+	+	+	+	+

Species	Status	Habitat	Central Catchment			Bukit Timah	
			S	M	N	J	P
7. *Neogerris parvulus* Stal, 1860	U	4	+	+	+	-	+
8. *Ptilomera tigrina* Uhler, 1860	FC	1,2	+	+	+	-	+
9. *Rheumatogonus intermedius* Hungerford, 1933	FC	1	+	+	+	-	-
10. *Rhagodotarsus kraepelini* Breddin, 1905	U	4	+	+	+	-	-
11. *Tenagogonus (Limnometra) ciliatus* Mayr, 1865	U	4	+	+	+	-	-
12. *Tenagogonus (L.) insularis* Hungerford & Matsuda, 1958	FC	3	+	+	+	+	+
13. **Tenagogonus (L.) octopunctatus* Hungerford, 1955	FR	3,5	+	+	+	-	-
14. *Tenagogonus quinquemaculatus* Miyamoto, 1967	FR	3,5	+	+	+	-	-
15. *Ventidius harrisoni* Cheng, 1965	FC	2	+	+	+	-	-
16. **Ventidius modulatus* Lundblad, 1933	FR	2	-	+	-	-	-
Family **VELIIDAE**							
17. **Microvelia albolineolata* Torre Bueno, 1927	FU	4	-	-	-	-	+
18. *Microvelia diluta* Distant, 1909	U	4	+	+	-	-	+
19. *Microvelia douglasi* Scott, 1874	U	4	+	+	-	-	+
20. *Microvelia plumbea* Lundblad, 1933	FR	3,4	+	+	-	-	-
21. *Microvelia genitalis* Lundblad, 1933	FR	3,4	+	+	+	+	+
22. *Microvelia* sp. 1	FU	3,4	+	+	+	+	+
23. *Microvelia* sp. 2	FU	3,4	+	+	+	-	+
24. **Neoalardus typicus* (Distant, 1903)	R	2	+	-	-	-	-
25. *Rhagovelia sumatrensis* Lundblad, 1933	FC	1,2	+	+	+	+	+
26. *Rhagovelia singaporensis* Yang & D Polhemus, 1994	FC	1,2	+	+	+	-	-
27. *Rhagovelia rudischuhi* Zettel, 1993	FC	2	+	+	+	+	+
28. *Strongylovelia* sp.	FC	2,5	+	+	+	-	-
Family **HYDROMETRIDAE**							
29. **Hydrometra carinata* J & D Polhemus, 1995	FR	3,5	-	-	+	-	-
30. *Hydrometra insularis* Hungerford & Evans, 1934	R	3,5	-	+	+	-	+
31. **Hydrometra longicapitis* Torre Bueno, 1927	FR	3,5	-	-	+	-	-
32. *Hydrometra maidli* Hungerford & Evans, 1934	U	3,5	+	+	+	-	+
33. **Hydrometra okinawana* Drake, 1951	FR	3,5	-	-	+	-	-
34. **Hydrometra papuana* Kirkaldy, 1901	FR	3,5	-	-	+	-	-

Species	Status	Habitat	Central Catchment			Bukit Timah	
			S	M	N	J	P
Family **MESOVELIIDAE**							
35. *Mesovelia horvathi* Lundblad, 1933	C	4,5	+	+	+	+	+
36. *Mesovelia vittigera* Horvath 1895	U	4,5	+	+	+	-	-
Family **HEBRIDAE**							
37. *Hebrus* sp.	U	4,5	-	+	+	-	-
Rare species (13)			**5**	**8**	**9**	**1**	**2**
Forest species (24)			**16**	**19**	**20**	**6**	**10**
Total species (37)			**27**	**31**	**29**	**7**	**17**

The poor diversity of Gerromorphan bugs in the Bukit Timah Nature Reserve was due to the small and relatively short streams with poorly grown aquatic vegetation and total absence of swamp. The middle and lower reaches of the streams were either at the edge of the forest or in the open country habitats. Inside the forest, parts of the streams dried up easily during the dry season as these were exposed due to a large number of fallen big trees in recent years. They probably also suffered from the drying effects of the numerous walking trails constructed in the reserve (Corlett, 1988). The isolated location and the small stream at a higher elevation in Jungle Fall Valley probably accounted for the lowest number of forest species of (6 out of 24) found in this primary forest.

The Central Catchment Nature Reserve has many swampy forest streams under well-shaded forest and these provide different microhabitats that are not available in the Bukit Timah Nature Reserve. Ten forested species found in the forest of the Central Catchment Nature Reserve, *Amemboa brevifasciata*, *Cryptobates rufus*, *Rheumatogonus intermedius*, *Tenagogonus* (L.) *octopunctatus*, *T. quinquemaculatus*, *Ventidius harrisoni*, *V. modulatus Microvelia plumbea*, *Rhagovelia singaporensis* and *Strongylovelia* sp. were not found in Bukit Timah Nature Reserve. With exception of *R. intermedius* (moderate to fast flowing water species), the other nine species were either found on swampy puddles or in slow flowing streams (Table 1). Four species of water measurers, *Hydrometra carinata*, *H. longicapitis*, *H. okinawana* and *H. papuana*, were collected from a weedy pool, in a semi-open country habitat, near the Nee Soon swamp forest. These were new records for Singapore and found only in this location. *H. papuana* is very rare in Peninsular Malaysia and was only recorded from lowland swamp forests (Polhemus & Polhemus, 1995b).

The Nee Soon Forest has the highest species diversity recorded in this study. Twenty (83%) of the 24 forest species and 9 (69%) of the 13

rare species were found in this location. This swamp forest was also the type locality for two recently described species, *Rhagovelia singaporensis* Yang & Polhemus (1994) and *Cryptobates rufus* Polhemus & Polhemus (1995a). The latter is rare (Figure 1) and distributed only in a few swampy streams, under well shaded forest, either near headwaters or in areas with iron hydroxide deposits (Murphy, 1990).

Metrocoris tenuicornis, *Rhagovelia sumatrensis* and *R. rudischuhi* were very common and were widely distributed in all forest streams, along with the less common *Tenagogonus insularis* at the swampy or quiet edges of the streams in all forested areas. *Ptilomera tigrina* was also common in most flowing forest streams with the exception of the stream at the Jungle Fall Valley.

Three gerrids, *Cylindrostethus malayensis* Polhemus, 1994 *(= C. costalis* Cheng & Fernando, 1969*), Esakia fernandoi* Cheng and *Ventidius hungerfordi* Cheng, previously collected from Sungei Seletar in 1965 (Cheng, 1965; Cheng & Fernando, 1969) were not found in this study. Sungei Seletar was the biggest stream in the Central Catchment Nature Reserve before it was converted into a reservoir in the early 1970s. The interruption of the water system probably accounted for the possible extinction of these three species that inhabited larger flowing water bodies. The survival of the present-day swamp forest species, especially those rare and localized ones will, therefore, be threatened by the change, loss or pollution of the swamp forest.

Entomovlia doversi, previously recorded from the MacRitchie forest (Murphy, 1990) was also not found in this study. It could have been carried over through the pipeline from the river in Johore (Malaysia) to the Upper Peirce Reservoir. Only a single specimen was collected after a heavy downpour that could have caused the water from the reservoir to flow into the forest stream. This species is common in pristine forest streams in Peninsular Malaysia. The single record of *Ventidius modulatus* was also from the same area.

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Water Beetles (Insecta: Coleoptera) in the Nature Reserves of Singapore

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Abstract

Of the 36 species of aquatic beetles recognised here, 17 are rated threatened. Two rare species of *Microdytes* (Dytiscidae) were only found in a small springlet in the Bukit Timah Nature Reserve. Nee Soon Swamp Forest has the highest diversity as well as the highest number of locally threatened water beetle species in the Nature Reserves.

Introduction

Conservationists and systematists nowadays agree that most species can only be saved when habitats of adequate size can be protected (Polhemus, 1993; Samways, 1994). However, conservation action with clear management strategies on a rather limited geographical scale is also frequently needed. This is especially true in areas that have already experienced considerable disturbance for a long period of time. To facilitate such action, biomonitoring groups are needed to determine the state of a given habitat. In wetland management, water beetles prove to be one such group, especially when microhabitats such as springs, low order streams or small waterholes require evaluation (Balke & Hendrich, 1991; Foster, 1991; Hendrich & Balke, 1993). The theoretical background characterising water beetle communities in terms of their conservation value, too, has been well worked out (e.g., Eyre & Rushton, 1989; Foster *et al.*, 1990; Richoux, 1994; Larson, 1997).

Balke and Hendrich (Hendrich & Balke, 1995; Balke *et al.*, 1997a, 1997b) have successfully utilised water beetles in the course of numerous environmental impact assessments in Germany, Malaysia and Indonesia. Several species of water beetle are to date not only included in regional red lists in Europe but also in the latest IUCN Red List of Threatened Animals (IUCN, 1996). Moreover, detailed conservation plans are in hand for two European species of diving beetles (Foster, 1996a, 1996b). These

are target species by the law in the European Community (EC), where every suitable aquatic habitat within their respective ranges must be monitored for the two beetle species before the land can be used for purposes other than conservation. As adequate observations on the distribution and biology of Southeast Asian water beetles have now become available, we believe that several factors could make them a useful biomonitoring group here as well: 1) the group is species rich; 2) they are present in virtually every type of fresh and brackish water habitat; 3) the group has numerous species confined to particular microhabitats; 4) knowledge of the group's taxonomic status is improving rapidly; 5) there is a good general knowledge of most groups; and 6) the group is represented by some large or especially colourful or enigmatic species, which may attract public interest (Hendrich, 1995).

The term 'water beetle' as used here, does not represent a phylogenetic unit, such as a family or superfamily. Rather, this is an arbitrary umbrella term for several beetle groups. For convenience, we refer to beetles spending most of their adult stage in the water as 'water beetles'. Of these, Dytiscidae (diving beetles) and Hydrophilidae (true water beetles) are the most species-rich groups in Singapore.

As early as the 1870s, Singapore was the type locality for numerous water beetles, such as the highly threatened *Copelatus minutissimus* Balfour-Browne, 1939. The holotypes of *Hydrovatus pisiformis* Biström, 1996 and *Hydrovatus stridulus* Biström, 1996 are the Saunders's material collected from Singapore in 1920s (Biström, 1996). Among the collections made by H.N. Ridley at the beginning of the century, *Lacconectus corayi* Brancucci, 1986, is a species no longer found in Singapore.

Yang (1992) listed 28 species of aquatic beetles from the Lower Peirce forest but her list is incomplete. Our aim is to evaluate the water beetle fauna based on recent surveys of the nature reserves in Singapore and identify the species that appear to be most threatened in Singapore and to discuss possible conservation action.

Methods

The survey area of this study included all water drainages in the Central Catchment Nature Reserve and Bukit Timah Nature Reserve (Figure 1) carried out during the period 1992 to 1997. Every type of water body was investigated. Those that appeared to be of particular interest according to our field experience were most intensively sampled. Interesting sites were revisited for observations on population dynamics and habitat succession.

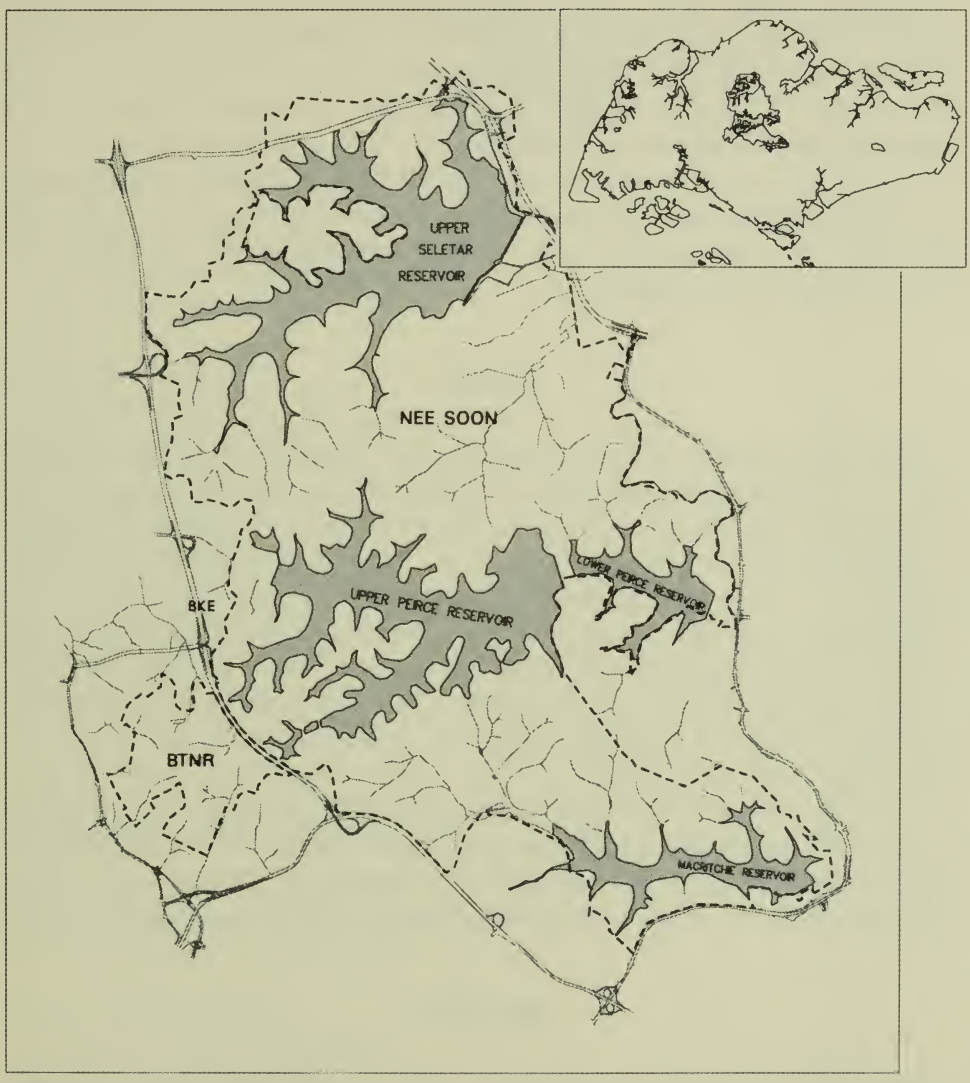

Figure 1. Map of Nature Reserves with an inset showing its location in Singapore. Central Catchment Nature Reserve (CCNR) and Bukit Timah Nature Reserve (BTNR) are separated by the Bukit Timah Expressway (BKE). Dotted lines = bounderies of Nature Reserves.

Larger water bodies were sampled with an aquatic dip net and a set of kitchen sieves of different diameters. The substrate obtained by strongly sweeping the net through mats of submerged grasses, aquatic plants, or open water, was placed on a 1 m x 1 m nylon panel for drainage. The substrate was then examined for the presence of the insects that, in most cases, within a couple of minutes exhibited themselves by running. Less active species or individuals were traced by carefully sorting the substrate with a pair of forceps. Beetles from springs and small streams could frequently be directly sampled with an aspirator or a pair of forceps.

Specimens collected were fixed in 70–90% alcohol, and brought to the Zoological Reference Collection (National University of Singapore) for further processing and setting. Species that could be identified on site were immediately released.

Results

A total of 36 species of water beetles from the survey are presented in Table 1. Several additional genera and species are currently under study and additional fieldwork is likely to provide additions to the list. A couple of species, most probably undescribed, are so far known only from Singapore. We have made some comments on ecological preferences of the species. Some species identified as 'target species' that deserve our special attention and conservation efforts have the following characteristics: 1) they are presently rare due to threats caused by man, 2) they have clear taxonomic status, 3) they have known habitat preferences, and 4) they have low ecological tolerance.

Of the 36 species surveyed in this study, 17 are threatened or identified as target species (Table 1). Fifteen species also occur outside the reserves ('other areas') but of these, only three are threatened. Thirteen species are restricted to different types of forest habitats of which 12 are target species.

Discussion

Though rather isolated from potential source areas that might contribute to a re-colonisation of wetlands in Singapore, our results suggest that the Nature Reserves contain communities of water beetles typical of lowland sites in Southeast Asia. However, the sites in Singapore are either relict sites (Bukit Timah Nature Reserve, Nee Soon Swamp Forest) or in many cases secondary (many parts of the Central Catchment Nature Reserve). Thus, their water beetle fauna deserve special attention. Two important areas are briefly discussed here:

Table 1. Preliminary checklist of water beetles from nature reserves in Singapore, with data on their ecology and conservation status. (**t** - temporary habitats; **p** - permanent habitats; **lo** - lotic species; **ln** - lentic species; **R** - restricted in distribution to forest sites; **bold** species names and numbers - target species.)

Species	Bukit Timah Nature Reserve	Nee Soon Swamp Forest	Mac Ritchie	Other areas	Ecology	Forest Species
Family **NOTERIDAE**						
Neohydrocoptus bivittis (Motschulsky, 1859)	-	+	+	+	p/ ln/ lo	-
Neohydrocoptus distinctus (Wehncke, 1883)	-	+	-	-	p/ ln/ lo	-
Neohydrocoptus frontalis (Régimbart, 1899)	-	+	-	-	p/ ln	-
Hydrocanthus indicus Wehncke, 1876	-	-	+	-	p/ ln	R
Family **DYTISCIDAE**						
Hydrovatus maai Biström, 1996	-	+	-	-	p/ ln	-
Hydrovatus pisiformis Biström, 1996	-	+	-	-	p/ ln	R
Hydrovatus pudicus (Clark, 1863)	-	+	-	-	p/ ln	-
Hydrovatus rufoniger (Clark, 1863)	-	+	-	+	p/ ln	-
Hydrovatus saundersi Biström, 1996	-	+	-	-	p/ ln	-
Hydrovatus sinister Sharp, 1882	-	+	-	+	p/ ln	-
Hydrovatus stridulus Biström, 1996	-	+	-	+	p/ ln	-
Hydrovatus sumatrensis Sharp, 1882	-	+	-	-	p/ ln	-
Microdytes elgae Hendrich, Balke & Wewalka, 1995	+	-	-	-	p/ lo	R
Microdytes pasiricus (Csiki, 1937)	+	-	-	-	p/ lo	R
Laccophilus pulicarius Sharp, 1882	-	+	-	+	p/ ln/ lo	-
Laccophilus ritsemae Régimbart, 1880	-	+	-	+	p/ t/ ln	-
Copelatus andamanicus Régimbart, 1899	+	+	+	+	t/ ln	R
Copelatus minutissimus Balfour-Browne, 1939	-	+	-	-	t/ ln	R
Lacconectus krikkeni Brancucci, 1986	+	+	-	-	p/ ln/ lo	R
Hydaticus bipunctatus Régimbart, 1899	+	+	-	+	p/ ln	-
Hydaticus sexguttatus Régimbart, 1899	-	-	+	-	p/ ln	R
Family **HYDROPHILIDAE**						
Allocotocerus muelleri (Kirsch, 1875)	-	-	+	+	p/ ln	-
Amphiops mater (Sharp, 1873)	-	+	+	+	p/ ln/ lo	-
Helochares lentus Sharp, 1890	-	+	-	+	p/ ln	-
Enochrus esuriens (Walker, 1858)	+	-	+	+	p/ ln/ lo	-
Enochrus gaggermeieri Hebauer, 1995	+	+	+	-	p/ ln/ lo	R
Paracymus evanescens Sharp, 1890	+	-	-	+	p/ ln	-
Coelostoma subditum d´Orchymont, 1936	+	-	-	+	P/ ln	-

Species	Bukit Timah Nature Reserve	Nee Soon Swamp Forest	Mac Ritchie	Other areas	Ecology	Forest Species
Family **HYDRAENIDAE**						
***Hydraena* sp. 1**	+	-	-	-	p/ lo	R
***Hydraena* sp. 2**	+	-	-	-	p/ ln	-
***Hydraena* sp. 3**	-	+	-	-	p/ lo	R
Family **GYRINIDAE**						
Dineutus spinosus (Fabricius, 1781)	-	-	+	-	p/ lo	-
Orectochilus productus Regimbart, 1883	-	+	+	+	p/ lo/ ln	-
Orectochilus oxygonus Regimbart, 1907	-	+	+	-	p/ lo/ ln	-
Orectochilus andamanicus Regimbart, 1883	-	+	-	-	p/ lo	R
Orectochilus corniger Zaitzev, 1910	-	+	-	-	p/ lo	R
36/ **17**	11/ **8**	25/ **11**	11/ **4**	15/ **3**		13/ **12**

Bukit Timah Nature Reserve

One of the most interesting sites we sampled is the small forest springlet in Taban Valley (Plate 1a) - a true relict site. It was found to contain viable populations of three target species, *Microdytes elgae* (Plate 1b), *Lacconectus krikkeni* and *Hydraena* sp. 1, while a fourth target species is represented by a relict population only, i.e., *Microdytes pasiricus*. For three of these species, this is the only known locality in Singapore (Table 1). *Microdytes* species are rare and rather localised in distribution not only in Singapore but also elsewhere (Hendrich, 1995; Hendrich & Balke, 1995). Thus, for the water beetles, the Bukit Timah site has conservation implications at the global level (Balke *et al.*, 1997a). At the local level, the site should be considered a potential source from which other suitable Singapore sites could be re-colonised, assuming viable populations could be maintained at Bukit Timah over longer periods of time.

Briffett (1990) listed the following threats to the Bukit Timah Nature Reserve: a) construction of the Bukit Timah Expressway has cut off the forest from the larger water catchment forest area, reducing the migratory interflow of flora and fauna (Fig. 1); b) the general drying-up of the forest threatens freshwater life that is now in danger of extinction; and c) heavy quarrying has resulted in many landslides over the years, causing several streams to be diverted or disrupted and endangering rare freshwater life.

With regards to management of the area, strategies to prevent further draining of the sites must be found. In fact, the above-mentioned water beetles could be used as an umbrella group here, and their protection will save many other rare animals, too. Further draining will, inevitably, make them disappear from the local scene.

Nee Soon Swamp Forest

Of the expected streamfauna, only one species, *Hydraena* sp. 3, was detected. The primary swamp nearby with a rich vegetation structure (Plate 1c) fully contained what should be there, i.e., a species-rich community of *Hydrovatus* species. Species of this genus are typical inhabitants of semi-exposed to exposed swampy sites and can thus be found in a wide variety of water bodies, such as Kent Ridge Park. However, a species-rich community, like Nee Soon Swamp Forest with at least six species, can only be found in primary environments for reasons not yet fully understood. Moreover, five of these *Hydrovatus* species have not been collected from localities other than Nee Soon Swamp Forest in Singapore (Table 1), and two of them are threatened fauna. It is notable that the populations of most species appear viable. However, a single specimen of the rare *Copelatus minutissimus* was collected here as well (Balke, 1994). This species is an inhabitant of small waterholes in forested areas and is among the rarest of the Southeast Asian water beetles (Balke, 1994). It probably faces extinction now, and we will include it in the next edition of the IUCN Red List of Threatened Animals. More sites deeper in the forest will have to be surveyed to attempt to detect a population of this species.

The whirligig beetles, *Orectochilus andamanicus* and *O. corniger*, were both found in well-shaded streams in the Central Catchment Nature Reserve swamp forest, mainly located in the Nee Soon area. *O. andamanicus* is a very rare and threatened species in Singapore as only one to two specimens per site were collected from the bigger streams. Although distributed from India to Peninsular Malaysia, it appears to be a very rare species (Mazzoldi, *pers. comm.*).

Without doubt Nee Soon Swamp Forest is the most important site for water beetles that warrants full conservation attention. Additional fieldwork will undoubtedly reveal many more species of interest. However, any lowering of the groundwater level would be disastrous to the swamp forest species. Management strategies should take into consideration the creation of small water holes in the forest that may serve as new breeding habitats for the rare *Copelatus* species and a range of other rare species not discussed here.

Conclusion

Preliminary surveys show that Singapore is home to a relatively rich water beetle fauna. It still offers the opportunity to discover either new or rare and little known species. However, those species adapted to primary habitats can be extremely vulnerable, some even on the verge of (local) extinction. To maintain the diversity presently observed, more proactive conservation actions need to be taken.

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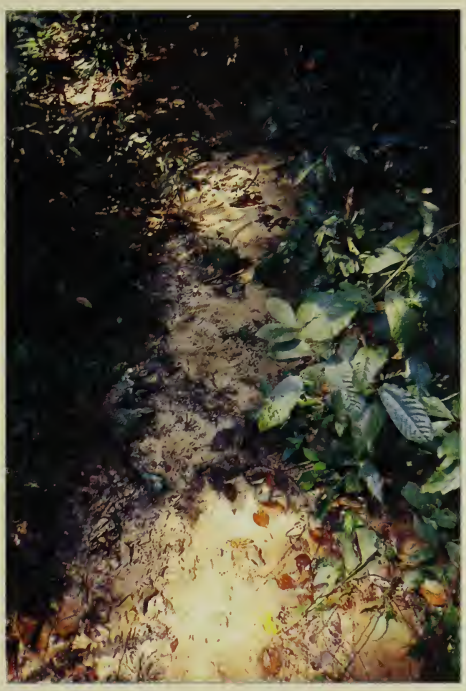

Plate 1a. Michael Balke

Plate 1b. Michael Balke

Plate 1c. Lars Hendrich

Plate 1d. Michael Balke

Plate 1. **a.** A small springlet in Bukit Timah Nature Reserve. **b.** *Microdytes elgae,* a rare dytiscid from Bukit Timah Nature Reserve. **c.** A species rich habitat for *Hydrovatus* in Nee Soon Swamp Forest. **d.** *Hydaticus bipunctatus*, a forest pool species.

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Odonata Biodiversity in the Nature Reserves of Singapore

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Abstract

An account is given of Odonata collected during the survey of the Nature Reserves. Most of the species described from Singapore material in A.R. Wallace's collection in 1856 still occur. A total of 79 species have been recorded within the Nature Reserves, including an endemic damselfly, *Drepanosticta quadrata*. Eight species are known only from Nee Soon Swamp Forest.

Introduction

The Odonata are a relatively well studied group whose aquatic larvae are carnivorous and thus not limited by distribution of specific plants, but which are known, at least in some cases, to be affected by the nutrient status and ambient properties of the water they live in.

The insect order Odonata (Plate 1) consisting of dragonflies and the smaller, more slender forms called damselflies, is represented in Southeast Asia by members of 14 families. Where known, all regional forms have aquatic larval stages so a biodiversity survey of the group must be related to the diversity of wetlands available in the area, even though many species range far from their breeding grounds as adults. However, there remain many species for which the larvae remain unknown and the existence of terrestrial larvae in other regions, such as in *Megalagrion oahuensis* in Hawaii (Williams, 1936), suggest some caution even in this assumption.

The Central Catchment Nature Reserve (CCNR) together with the adjacent Bukit Timah Nature Reserve lies near the centre of Singapore, remote from the coast so that essentially maritime species can be at most only casual visitors. The function of the area as a water catchment implies that polluted waters are essentially excluded, though in fact some institutional land, golf courses, parkland and a closely monitored zoological garden do fall within its drainage area.

The reserve area lies wholly within the central granitoid core of the island at the focus of the main headwaters of streams flowing north, south and east, now impounded to form four reservoirs supplying the potable

water grid of the city, and whose input is supplemented by water imported from Johore. The high ground is largely 'tree country' in the sense of Johnson (1967), though of very varied forest quality, mostly a mosaic of secondary vegetation with a few pockets retaining primary character.

The odonate fauna may be expected to reflect the extent to which the original forest stream, pool and swamp biota have survived the intense human exploitation over almost two centuries as described by Corlett (1992). It will also reflect the impact of large water bodies wholly foreign to the original hydrography of the island, the loss of major open streams to impoundment or canalisation, and, most recently, the conversion of a largely rural and agricultural terrain to one now wholly urban, industrial and recreational. This study of the CCNR can only address some of these aspects. An account of the odonate fauna of the island of Singapore as a whole is deferred to a later communication.

History

The first collection of Singapore dragonflies seemed to be that assembled by Alfred Russell Wallace during his six-month stay in 1854 prior to his travels through the Malay Archipelago. No list was ever published, but in a short paper entitled 'The entomology of Malacca', Wallace (1855) mentioned that in Malacca he '... nearly doubled my collection, which now amounts to 72 species of true dragonflies.' He must have taken over 36 species in Singapore but even so only 26 species have been accounted for in literature available to me. None of the Wallace material could be unequivocally assigned to the existing CCNR since his material was simply labelled 'Singapore'.

The next important contribution was by Laidlaw (1931) and this time, using material in the Raffles Museum, he gave actual location, date and collector, writing 'I have attempted to note all records for Singapore as it occurs to me that such records may be of particular interest in view of the many changes which have been in progress in the Island in the last hundred years or so.' Laidlaw himself seemed never to have collected in Singapore and the material came from collectors who were not specialists in Odonata capable of specific search. Most locations mentioned were not within the reserve.

The next important contribution was a comprehensive catalogue for the Malesian region (Lieftinck, 1954) in which Singapore island is frequently cited specifically but without internal locations. Although many interesting new records were made, it was striking that very few of the forest species found by Wallace had been recollected. Far from indicating their extinction

however, this appeared only to reflect limitations of the collecting habits of the workers concerned. After the Lieftinck catalogue, only a few small lists were on record that could be localised to the CCNR area (Paulson, undated; Iwasaki, 1981; Kiauta & Kiauta, 1982; Yokoi, 1996) besides occasional notes in special literature (e.g., Murphy, 1994).

Methods

During the formation of the collection on which this paper is based, an attempt was made to reach all known stream-lines in the reserve, many of which were remote from normal access (Figure 1). A policy of mapping all penetrations of the area was adopted and in fact the geographical survey became a significant component of the work in its own right. The problem of locating and recording individual collecting sites in such remote terrain presented some difficulty.

Figure 1. Locations of sampling sites.

Since the CCNR has most (three out of four) of its stream systems impounded to form reservoirs, this allowed us to code the sectors in the following manner. In each reservoir, the major inlets were lettered anticlockwise (A being the outlet) and streams entering each inlet received this code with appropriate subscripts to identify them and their various tributaries. A similar system was found workable in the unimpounded Nee Soon Swamp Forest.

Adult dragonflies were collected by hand-net at selected points during the mapping operation, wherever local conditions permitted. Because many forest streamlines were choked with hooked rattans or pandans, this was inefficient and some records by sighting alone had to be made. In genera with closely similar species (e.g., *Gynacantha* and *Vestalis*) only a generic name could be applied and in such cases had to be discounted in mapping distribution. A limited amount of larval collection and rearing was also undertaken. Identification relied on available regional literature and an unpublished generic key of my own, and all have been checked by M. Hämäläinen. Names conform to those in van Tol (1992).

Results

Table 1 lists the dragonfly and damselfly species collected from the reserve area during the survey period 1994 to 1998 and some previous confirmed records. A total of 79 Odonate species have been recorded from within reserve limits out of a total of more than 100 now known from the whole island. This total now excludes some species previously reported in error. The Singapore list now included 36 species not previously recorded from the State, most of these taken during the period of this survey although not all from within the reserve area. Some of these were common species, which were to be expected but some are rarities of some significance. For example, *Aethriamanta aethra* (Plate 2a) is the first record for Singapore and the Malay Peninsula and *Orthetrum luzonicum* is normally considered a montane species but found in Singapore.

Probably the commonest dragonfly in Singapore is *Neurothemis fluctuans* whose brown-winged males are seen everywhere around marshy spots, grassy pools and open stream sides. It penetrated the CCNR along road-sides and open tracks and can be common quite deep in open secondary forest. Yet, this species was never associated with true forest streams. Its very abundance might have contributed to our failure to record the related *Neurothemis disparilis*, reliably recorded from Singapore (Laidlaw, 1931), which perhaps could be mistaken for a teneral or female of *N. fluctuans*.

Table 1. Dragonflies and damselflies collected during the Nature Reserves survey. (1–New Record for Singapore, 2–Singapore is type locality)

Species	Status in Nature Reserves	Singapore general
Suborder **ZYGOPTERA** (Damselflies)		
Family **Amphipterygidae**		
Devadatta argyoides[2]	Local. Bukit Timah	-
Family **Calopterygidae**		
Vestalis amethystina	Frequent	-
Vestalis amoena	Local (Nee Soon)	-
Family **Chlorocyphidae**		
Libellago aurantiaca[2]	Local (Nee Soon system only)	-
Libellago hyalina[1]	Rare (Nee Soon only)	-
Libellago lineata	Rare	-
Family **Euphaeidae**		
Euphaea impar[1]	Local	-
Family **Lestidae**		
Lestes praemorsus[1]	Locally common (MacRitchie only)	-
Platylestes heterostylus	?Bukit Timah	-
Family **Megapodagrionidae**		
Podolestes orientalis[1]	Local	-
Family **Platycnemidae**		
Coeliccia albicauda[1]	Rare. 1 Seletar U	-
Coeliccia octogesima[2]	Locally common	-
Copera marginipes	Rare	Common. widespread
Family **Platystictidae**		
Drepanosticta quadrata[2]	Common	-
Family **Pseudagrionidae**		

Species	Status in Nature Reserves	Singapore general
Aciagrion hisopa	Occasional	Occasional
Agriocnemis femina	Local	Common, widespread
Agriocnemis nana	Local	-
Amphicnemis gracilis[1]	Swamp forest only	-
Archibasis melanocyana[1]	?Rare, reservoir	-
Archibasis viola[1]	Local	-
Argiocnemis rubescens	Local	-
Ceriagrion cerinorubellum	Local	Common, widespread
Ischnura senegalensis[?1]	Local	Common, widespread
Onychargia atrocyana[2]	Occasional	Old record (type)
Pericnemis stictica[1]	Frequent	? any bamboo area
Pseudagrion australasiae	Common, reservoirs	Occasional
Pseudagrion microcephalum	Common, open streams	Common
Pseudagrion pruinosum[1]	Rare	-
Pseudagrion rubriceps[1]	Rare	-
Teinobasis ruficollis[2]	Local U.Mac.conv.	-
Family **Protoneuridae**		
Prodasineura collaris	Local, widespread	-
Prodasineura interrupta[2]	Local, Nee Soon catchment	-
Prodasineura notostigma[2]	Local, widespread	-
Suborder **ANISOPTERA** (Dragonflies)		
Family **Aeschnidae**		
Anax guttatus	1 (mist net)	Common
Gynacantha spp.	Visual sightings	Occasional
Oligoaeschna amata	Rare	Old record
Tetracanthagyna plagiata	Rare, Nee Soon Swamp Forest	Old record
Family **Corduliidae**		
Epophthalmia vittigera	?Common (reservoirs)	Occasional
Family **Gomphidae**		
Burmagomphus divaricatus	Local, Nee Soon SF	-
Heliogomphus kelantanensis[1]	Local, Nee Soon SF	-

Species	**Status in Nature Reserves**	**Singapore general**
Ictinogomphus decoratus	Common, reservoirs	Common
Macrogomphus quadratus[1]	Local but widespread	-
Microgomphus chelifer[1]	Local (Nee Soon SF)	-
Paragomphus capricornis	Rare	-
Family **Libellulidae**		
Acisoma panorpoides	Local	Common, widespread
Aethriamanta aethra[1]	V. rare, 1 @ Banir	1 @ Lim Chu Kang
Aethriamanta gracilis	Local	Common, widespread
Agrionoptera sexlineata[2]	Local	Local
Brachydiplax chalybea	Local	Common, widespread
Brachythemis contaminata	Rare	-
Camacinia gigantea[1]	Rare	Rare
Chalybiothemis fluviatilis	Local (MacRitchie)	No other records
Cratilla metallica	Occasional	-
Crocothemis servilia	Occasional	Common
Diplacodes nebulosa	Local	Common
Diplacodes trivialis	Local	Common
Lathrecista asiatica	Occasional	Frequent
Lyriothemis cleis[1]	Occasional	-
Nannophya pygmaea	Local but widespread	Local
Neurothemis fluctuans	Very Common	Very Common
Orchithemis pulcherrima	Common	-
Orthetrum chrysis	Common, open areas	Common
Orthetrum glaucum	Local	Common
Orthetrum luzonicum[1]	Local	Rare
Orthetrum sabina	Common	Common
Orthetrum testaceum	Common	Common
Pantala flavescens	Common	Common
Potamarcha congener	Occasional	-
Rhodothemis rufa	Local	Common
Rhyothemis obsolescens	Local	Local
Rhyothemis phyllis	Common	Common
Rhyothemis triangularis[1]	Local	-
Risiophlebia dohrni[1]	Rare, swamp forest	-
Tholymis tillarga	Common	Common

Species	Status in Nature Reserves	Singapore general
Trithemis aurora	Common	Common
Trithemis festiva[1]	Local (open stream)	Local
Trithemis pallidinervis	Local	Frequent
Tyriobapta torrida	Frequent	-
Urothemis signata[1]	Occasional	Frequent

More locally, open ground with wet areas supports the tiny *Nannophya pygmaea*, *Rhyothemis obsolescens* and common damselflies such as *Agriocnemis femina* and *Ceriagrion cerinorubellum*. The blue coloured *Pseudagrion*, *P. microcephalum* (Plate 2b) and *P. australasiae*, occur along open stream lines as well as around reservoirs. Large active libellulid dragonflies hover over and near open waters and include *Orthetrum sabina*, *O. chrysis*, *O. testaceum*, *O. glaucum* and *O. luzonicum*, *Crocothemis servilia*, *Rhodothemis rufa*, *Trithemis aurora*, *T. festiva*, and the smaller *Aethriamanta gracilis*, *Brachydiplax chalybea* and *Diplacodes nebulosa*. The large gomphid *Ictinogomphus decoratus* is also very common.

Open spaces far from water, especially high ground such as the helicopter landing site near Chestnut Avenue, also have large populations of *Rhyothemis phyllis*, *Pantala flavescens* and *Trithemis aurora*, and some rare records such as *Camacinia gigantea*. Road-sides with temporary pools may have local populations of *Diplacodes trivialis*.

Although these common species are likely to be those usually seen by the public, very few of them penetrate into truly closed forest (an exception is *Orthetrum chrysis*), and it is the forested water bodies that were the principal object of the present survey. Of the nine species originally collected by Wallace in 1854 and said to be based on Singapore material, all but one (*Libellago stigmatizans*) still survive and are found in the reserve. Of the others, *Libellago aurantiaca* is now confined to the Nee Soon drainage (but would probably have been collected by Wallace in the upper reaches of the Pang Sua, which would have been swamp forest at that time). Of the others, *Coeliccia octogesima* (Plate 3a), *Drepanosticta quadrata* (Plate 3b), *Onychargia atrocyana*, *Prodasineura interrupta* (Plate 3d), *P. notostigma* and *Agrionoptera sexlineata* are still found scattered widely throughout the central catchment area near forested streams or swamps. *Devadatta argyoides* is now virtually confined to Bukit Timah and *Teinobasis ruficollis* to secondary forest pools at the stream convergence of the Upper MacRitchie basin. Interestingly, this latter point would have been accessible by cart track in Wallace's day, though it is more likely that the species were more widespread in his day

Eight species now appear to be totally confined to the Nee Soon Swamp Forest, *Burmagomphus divaricatus, Heliogomphus kelantanensis, Libellago aurantiaca, L. hyalina, Microgomphus chelifer, Risiophlebia dohrni, Tetracanthagyna plagiata,* and *Vestalis amoena*. Six others, *Amphicnemis gracilis, Macrogomphus quadratus* (Plate 2c), *Orchithemis pulcherrima* (Plate 2d), *Prodasineura collaris, P. interrupta* and *P. notostigma*, are also common there, but extend elsewhere in forested streamlines.

Seven other species, *Archibasis viola, Drepanosticta quadrata, Euphaea impar, Onychargia atrocyana, Podolestes orientalis* (Plate 3c), *Tyriobapta torrida,* and *Vestalis amethystina*, occasionally appear in the fringes of the swamp forest but are more typical of feeder streams or swamps elsewhere in the catchment. Of these, *Euphaea impar* and *Vestalis amethystina* are believed to favour higher water speeds and often indicate erosion areas such as those in the Upper MacRitchie basin (Figure 2). The distinctive larva of *Euphaea* is found among trapped leaves in fast water.

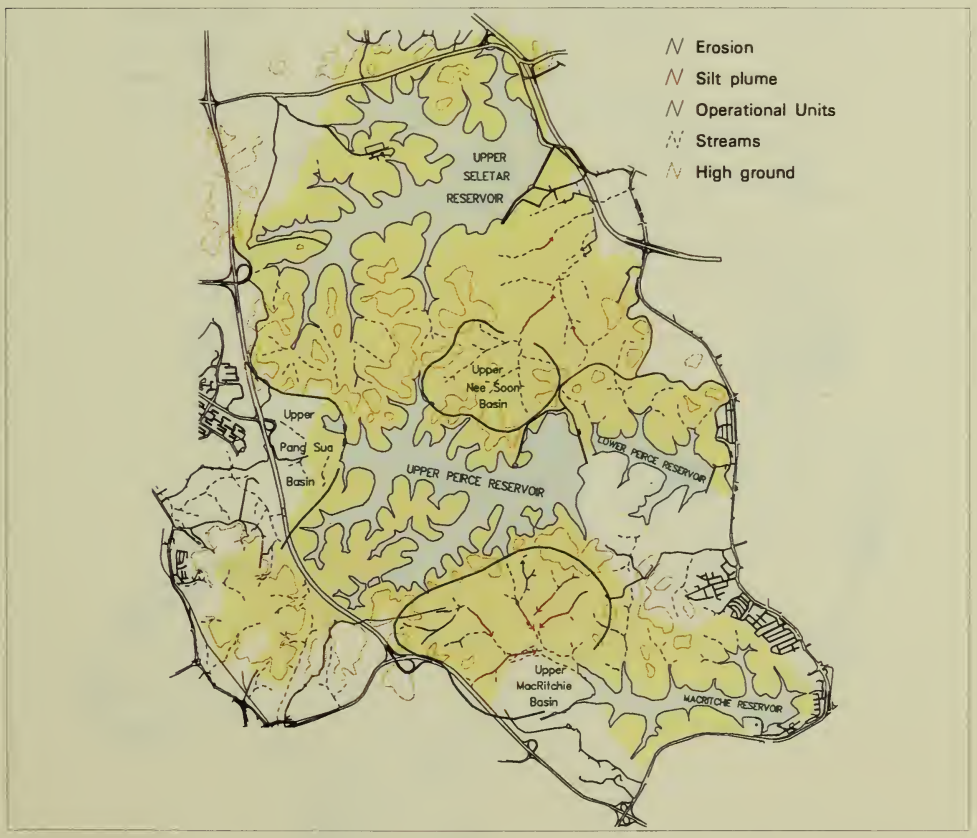

Figure 2. Sites of erosion processes currently or historically likely to have affected dragonfly distribution.

Secondary swamp forest variants also exist (Figure 3). At the head of inlets of the low-lying reservoirs (MacRitchie and Lower Peirce) where the stream profile is very shallow, long narrow 'ribbon swamps' with braided stream lines have developed since the impoundment. They have a very depauperate tree flora but offer conditions in which some of the swamp forest odonates, such as *Amphicnemis* and *Macrogomphus*, have become established. Higher up the water courses, uneroded streams often alternate between fast flowing reaches and level swampy reaches which I call 'step swamps'. Whether this is a general feature of granitic topography or perhaps a consequence of prior land use is uncertain, but some of the step swamps are particularly favoured by *Drepanosticta, Coeliccia, Podolestes* and *Archibasis viola*, though these species can certainly be found elsewhere.

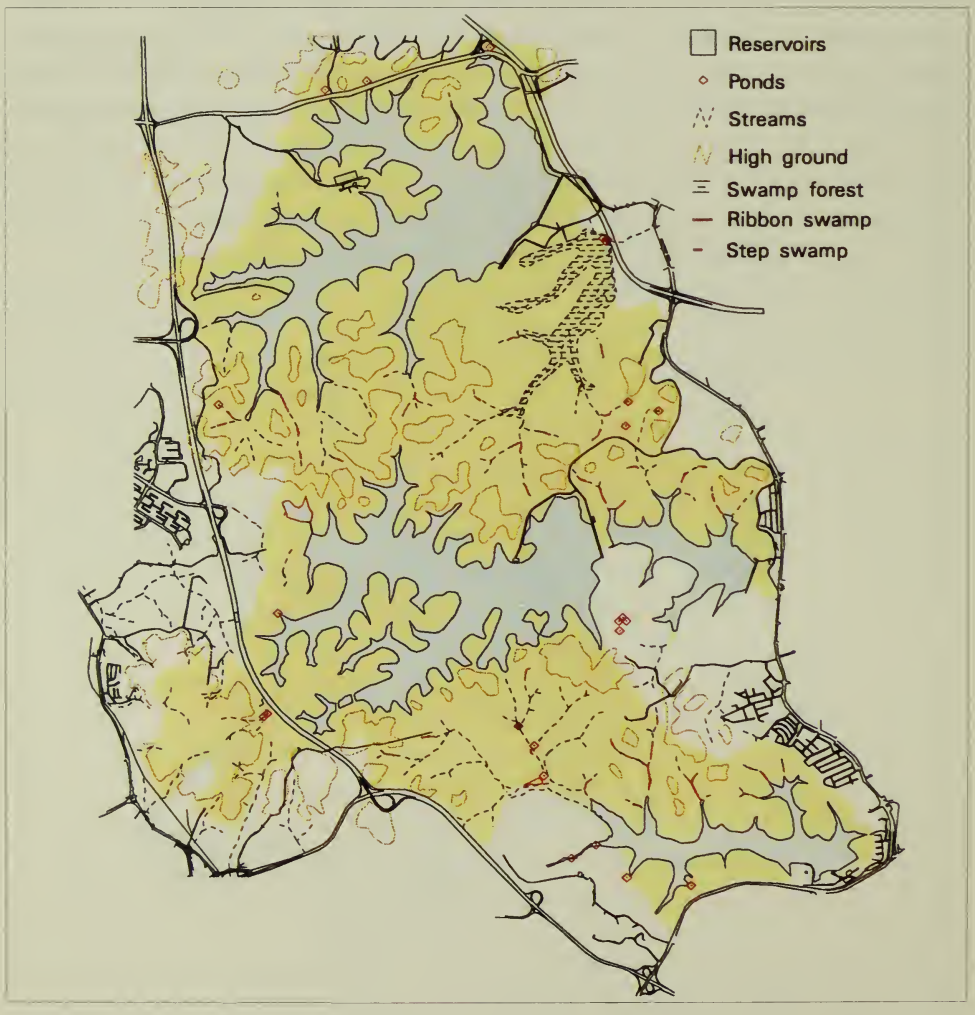

Figure 3. Distribution of various kinds of water body in and near the reserve area.

As an example of species distribution, Figure 4 plots records of the three species of *Prodasineura*. None of these have been found outside the CCNR in Singapore and the genus is not known from Bukit Timah. Too few larvae have been seen to throw light on breeding conditions and only one of these was reared to adult so we do not know how to discriminate species from larvae. Nevertheless, adult distribution shows intriguing differences. *Prodasineura collaris* is widely scattered and appears associated with still waters choked with leaves. *Prodasineura notostigma* is common over deeply-shaded open streams. *Prodasineura interrupta* occurred together with *P. notostigma* in the lower part of the Nee Soon Swamp Forest and was widespread in the upper Nee Soon basin where it was the only species seen. It remains unexplained why this species is, on present evidence, confined to the Nee Soon catchment, since it is found in riparian galleries not obviously different from those in other drainage systems. The absence of *P. notostigma* from the Upper Nee Soon basin is also remarkable.

Figure 4. Distribution of three species of *Prodasineura*.

The convergence streams and pools of the Upper MacRitchie basin (Figure 5) support some species not, or rarely, seen elsewhere. The artificially straightened lower reaches of streams H and J caused berms to impound ponds to which several rare species are now confined, notably *Argiocnemis rubescens* and *Teinobasis ruficollis*. Some of these ponds are fairly open with scattered emergent small trees of *Alstonia spatulata* but have well shaded edges, while smaller ponds under full shade also exist. Other species breeding here include *Tyriobapta* and *Lathrecista* that are more widespread. Also restricted to this area, but along the open streams, is *Agriocnemis nana*. Why this location should have localised species is not entirely clear. However it is speculated that these forest pools may represent a habitat formerly more widespread in lowland Singapore in situations now lost to urbanisation or cultivation. The species may have succeeded in colonising this secondary habitat before their original and natural habitats were completely destroyed. However there are possibly other contributing factors.

The recent appearance of *Pseudagrion pruinosum* and *Copera marginipes* in the nearby meter pond area may relate to seepage of enriched water from Upper Peirce, as may the presence of the calcareous alga *Chara*.

Figure 5. Location of the convergence streams and pools of the Upper MacRitchie basin.

Upper Peirce Reservoir is now principally a holding reservoir for water imported from Johore and has potassium levels ten times higher than that of purely local water. Similar levels occur in some headwater streams originating close to Upper Peirce but which feed into MacRitchie. Water quality may also be a factor in the presence of *Devadatta* in one location (MacRitchie stream J). This species is otherwise restricted to Bukit Timah whose streams also show higher potassium levels due to drainage from freshly decomposing granite. Throughout its wide range in South East Asia, *Devadatta* seems intolerant of the nutrient deficient waters typical of forest streams on deep mature regolith. In addition, meter pond stream H (Figure 5) until recently received water through the Kallang Tunnel also originating in Johore and the possibility of larvae having washed through cannot be discounted.

Dragonflies are less often seen in dry-land forest remote from water but certainly do occur there. This is especially true of females that may tend to leave the breeding sites to forage before returning to mate and lay eggs. Females of *Coeliccia octogesima, Vestalis amethystina* and *Amphicnemis* have been taken so, but never their males. This may be why *C. octogesima* was described from a female, while the actually more commonly seen males were unknown until this present survey. However, *Tholymis tillarga* males are quite often seen flying in deep shade. This species is commonly attracted to lights and is widely considered to be nocturnal, but in the forest it is clearly active in daytime. *Cratilla metallica* and one or more of the three species of *Gynacantha* known from Singapore are also seen in deep forest. *Pericnemis stictica* and *Lyriothemis cleis* breed in 'phytotelms' (tree-holes and bamboos holding water) and are apparently widespread, though not often seen as adults. Their habits would not restrict them to stream-lines.

The reservoirs themselves support some species not entering forest. The oldest reservoir, MacRitchie, has three species not found elsewhere, *Archibasis melanocyana, Chalybiothemis fluviatilis*, and *Lestes praemorsus* as well as common open-water species of *Orthetrum*, *Rhyothemis*, *Trithemis*, *Epophthalmia* and *Ictinogomphus, which* are found around all reservoirs and open streams throughout the island. The reservoirs have not been a major issue during this survey although, of course, some material has been assembled, including the three species confined to MacRitchie. Several species recorded only from other reservoirs are known to be associated with unstable or even maritime conditions (e.g., *Trithemis pallidinervis* and *Ischnura senegalensis).*

Of species known to be present in Singapore but not recorded during this survey of the CCNR, several are high flying or nocturnal forms that are certainly there but were not collected by the methods used. Several

very common forms associated with small open water bodies, maritime conditions or enriched or polluted waters are either absent or extremely local, as would be expected in a controlled water catchment where such habitats are excluded. Thus *Brachythemis contaminata* that is one of the commonest species around shallow grassy ponds such as exist in the nearby golf courses, is hardly ever seen even in immediately adjacent arms of the reservoirs.

Discussion

Of the recorded names accepted as valid, seven are considered suspect as records. *N. tullia*, *P. laidlawii* and *Rhinocypha* sp. were listed from Nee Soon in a publication in Japanese attributed to Iwasaki (1981) after his death. On translation this proved to be his edited field notes, originally using Japanese names of Japanese species with which he was familiar, but with scientific names added apparently by an editor. He appeared to have been unfamiliar with tropical species at the time of collection and used Japanese species names as a rough guide, the editor then attempted to match these with known regional species. His exact collecting sites were mapped and have been revisited but none of his species were found there. His *N. tullia* may be *Tyriobapta torrida*, and *P. laidlawii* may be *Prodasineura collaris*, the only species now found at that site. Several other names though valid are to some extent suspect. Thus, *Vestalis amethystina* is recorded from where we now find only *Vestalis amoena*, possibly because former records of *V. amoena* from Singapore have been revised as *V. amethystina* (Lieftinck, 1965) and we now know that both species occur. *Agriocnemis pygmaea* was reported with a note that its thorax was unusually thick compared with Japanese material. Today the site has only *Agriocnemis femina*. That there could have been faunistic changes is, of course, possible especially since oiling for mosquito control is carried out at the site specified.

One record of *N. intermedia* by Yokoi (1996) from a site near the Zoological Gardens is unlikely since the species is Indian. Possibly this was *Neurothemis disparilis,* also a species we have failed to recognise. Material from Bukit Timah attributed to *Indolestes* by Murphy and given to D. Paulson in 1980 may be the origin of his informally circulated record of *Platylestes heterostylus*.

The widely cited records of *Urothemis abbotti* appear to originate from the original author (Laidlaw, 1927) mentioning a damaged female Singapore specimen when describing *U. abbotti* from Thailand. All material of this genus examined since have proved to be *Urothemis signata bisignata*. A record of *Orolestes wallacei* by Laidlaw (1931) was based on a specimen

"said to be in the British Museum and not seen by me...". It is a possible record but remains unconfirmed to this day.

A total of 24 species collected during this survey are new records for Singapore (Table 1). Some of these are common and were to be expected. In total, 79 species have been recorded as documented specimens from within reserve limits with a further eight likely to be present but with habits precluding collection, such as being nocturnal or high flying. The species listed as now confined to Nee Soon Swamp Forest were probably more widespread in the past. *Vestalis amoena* was historically recorded (correctly) from Bukit Timah. Two species are distinctive of Bukit Timah - *Indolestes* and *Devadatta argyoides*. All other species so far known in Bukit Timah also occur in the CCNR. The hill does, however, need more intensive survey than it has received.

An additional eight species recorded more or less reliably in the literature have not been seen (or at least recognised) but are not necessarily forms to be expected in the reserve area. Some may have habits (such as high perching) that preclude easy collection and only an extended rearing programme would be likely to reveal them. Only for three species, normally associated with habitats such as large rivers that have now been totally converted in Singapore, can extinction be strongly suspected.

Five historically recorded species may have become extinct - *Brachygonia oculata*, *Burmagomphus plagiatus*, *Dysphaea dimidiata*, *Libellago stigmatizans* and *Neurobasis chinensis*. *Burmagomphus plagiatus* was a reliable larval record by Lieftinck (1964) from the lower reaches of Seletar River now converted to a concrete canal. In addition, *Neurothemis disparilis*, *Agriocnemis pygmaea* and *Rhyothemis pygmaea* have not been seen by me, although records of the latter two by Paulson in 1980 are recent. Even so, none of the extinctions can be taken as absolutely certain, although very probable.

Among Odonata, only one species (*Drepanosticta quadrata*) is believed totally endemic to Singapore, but it is common in several areas and is not threatened. The genus is known for having many extremely localized species.

Many species are more or less restricted to tree covered land and most of these found only in the CCNR and/or Bukit Timah. These include the eight species mentioned above as only known today from the Nee Soon Swamp Forest.

The deteriorating conditions in the Upper MacRitchie Basin are reflected in the odonate fauna in several ways. An apparent extinction that occurred within the last three decades concerns *Neurobasis chinensis* (last taken in Singapore in 1970), extinct probably due to siltation of the stream marked Jc (Figure 5) where it occurred by construction of the Pan Island

Expressway in 1972. A stand of mature riparian swamp forest in the upper reach of that stream died out at that time. By 1990 good regrowth had developed but then the expressway was widened and the whole streamline again smothered by a new silt surge. Well-established local populations of *Amphicnemis* and *Coeliccia* died out, together with the young secondary swamp forests in which they had become established between 1993 and 1994. Possibly *Onychargia*, not seen there since 1989, was also lost. These species, which are still present elsewhere, will probably recolonise sites that revert to forest cover. In the lower reach, a population of *Agriocnemis nana* was destroyed along with other species and only *Trithemis aurora*, a 'weedy' species not formerly present, is found there today.

Finally the question of seasonality has hardly been addressed. Most species are not significantly seasonal on a regular basis, but some migrants may be affected by the monsoons. Periods of drought may cause smaller water bodies to dry out entirely with possible long term consequences for species with poor dispersal.

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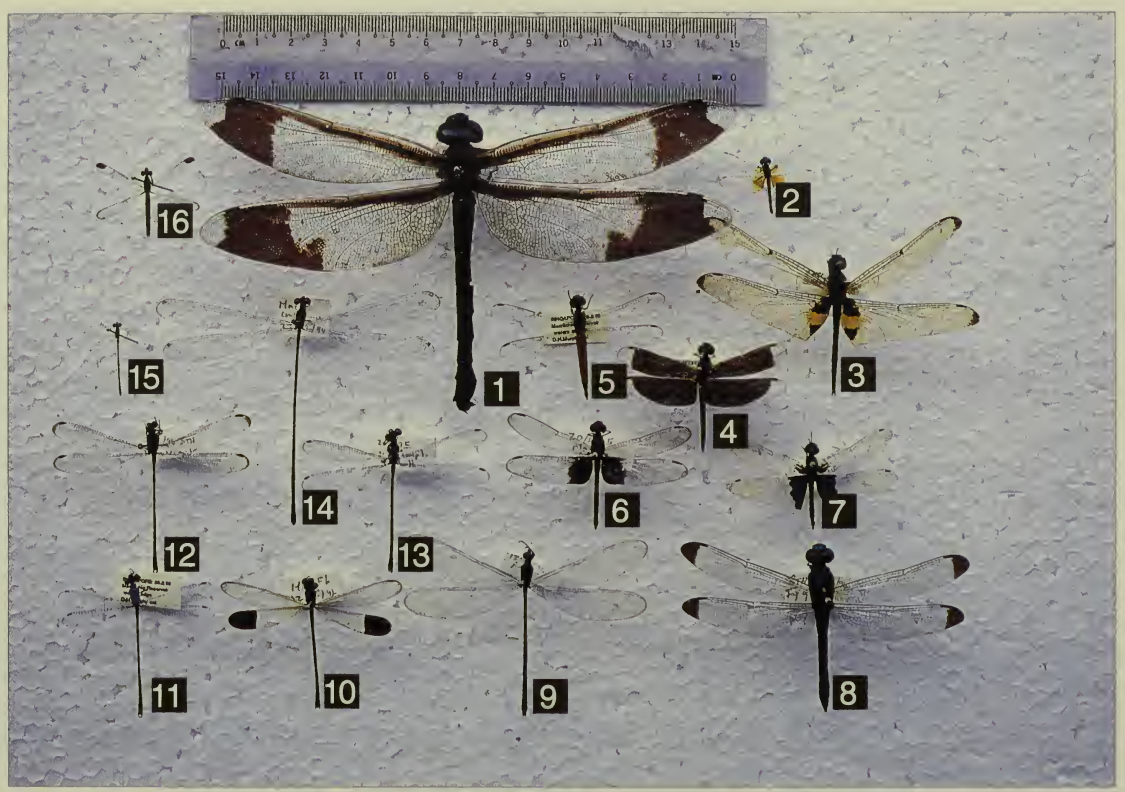

Plate 1. Some Singapore dragonflies and damselflies to show relative sizes; 1—8 Suborder Anisoptera, 9—16 Suborder Zygoptera. **1**. female *Tetracanthagyna plagiata*. **2**. *Nannophya pygmaea*. **3**. *Rhyothemis phyllis*. **4**. male *Neurothemis fluctuans*, two commonly seen open country species. **5**. male *Orchithemis pulcherrima*, the commonest dragonfly over forest streams. **6**. male *Tyriobapta torrida*, a forest species often seen perching on the vertical side of tree trunks. **7**. male *Rhyothemis triangularis*. **8**. *Cratilla metallica*, one of the larger Libellulids. **9**. *Vestalis amethystina*. **10**. *Euphaea impar*. **11**. *Lestes praemorsus*. **12**. *Devadatta argyoides*. **13**. *Podolestes orientalis*. **14**. *Pericnemis stictica*. **15**. *Agriocnemis femina*. **16**. *Libellago aurantiaca*.

Plate 2. **a**. *Aethriamanta aethra*, a first record for Singapore. **b**. *Pseudagrion microcephalum* occurs along open waters such as grassy streams and edges of reservoirs. **c**. *Macrogomphus quadratus*. **d**. *Orchithemis pulcherrima*.

Plate 3. Some damselflies widespread in forest stream-lines (a—c) and a species from the Family Protoneuridae (d). a. Male *Coeliccia octogesima*. **b.** *Drepanosticta quadrata* is believed to be endemic to Singapore. **c.** *Podolestes orientalis*. **d.** *Prodasineura interrupta*.

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Mammals, Reptiles and Amphibians in the Nature Reserves of Singapore - Diversity, Abundance and Distribution

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Abstract

The diversity of mammals, reptiles and amphibians is still high in the Nature Reserves with a total of 141 indigenous species recorded in the past decade, comprising 44 mammals, 72 reptiles and 25 amphibians. During the four-year survey, there were 10 additions to Singapore's checklist of mammals, reptiles and amphibians, and 13 other species were rediscovered compared with four and ten, respectively, recorded during the six-year period prior to the survey. This is a clear indication that our Nature Reserves may still hold many species that are either not recorded for Singapore or are thought to be extinct. The Nature Reserves are probably the last refuge for 74 forest-dependent species and 80 species whose populations are of such low numbers that they are threatened with extirpation. Bukit Timah, Nee Soon and MacRitchie are the richest in biodiversity and, hence, are key areas for conservation. They should be set aside as core zones with the incorporation of Mandai and Lower Peirce.

Introduction

At the inception of the Nature Reserves survey, the Vertebrate Study Group of the Nature Society (Singapore) was requested to survey the mammals, reptiles and amphibians, the scope of which included:

1. an inventory of species,
2. information on the abundance of species,
3. a study of the distribution patterns of species in relation to vegetation type, geophysical, historical and human factors, and
4. information on the conservation status of endangered and rare species.

Methodology

The Nature Reserves were divided into six zones, namely Bukit Timah, MacRitchie, Upper Seletar, Lower Peirce, Nee Soon and Mandai. These

zones were further divided into 23 sectors. The number of sectors per zone was determined by taking into account the size, geography and accessibility of the zone (Figure 1).

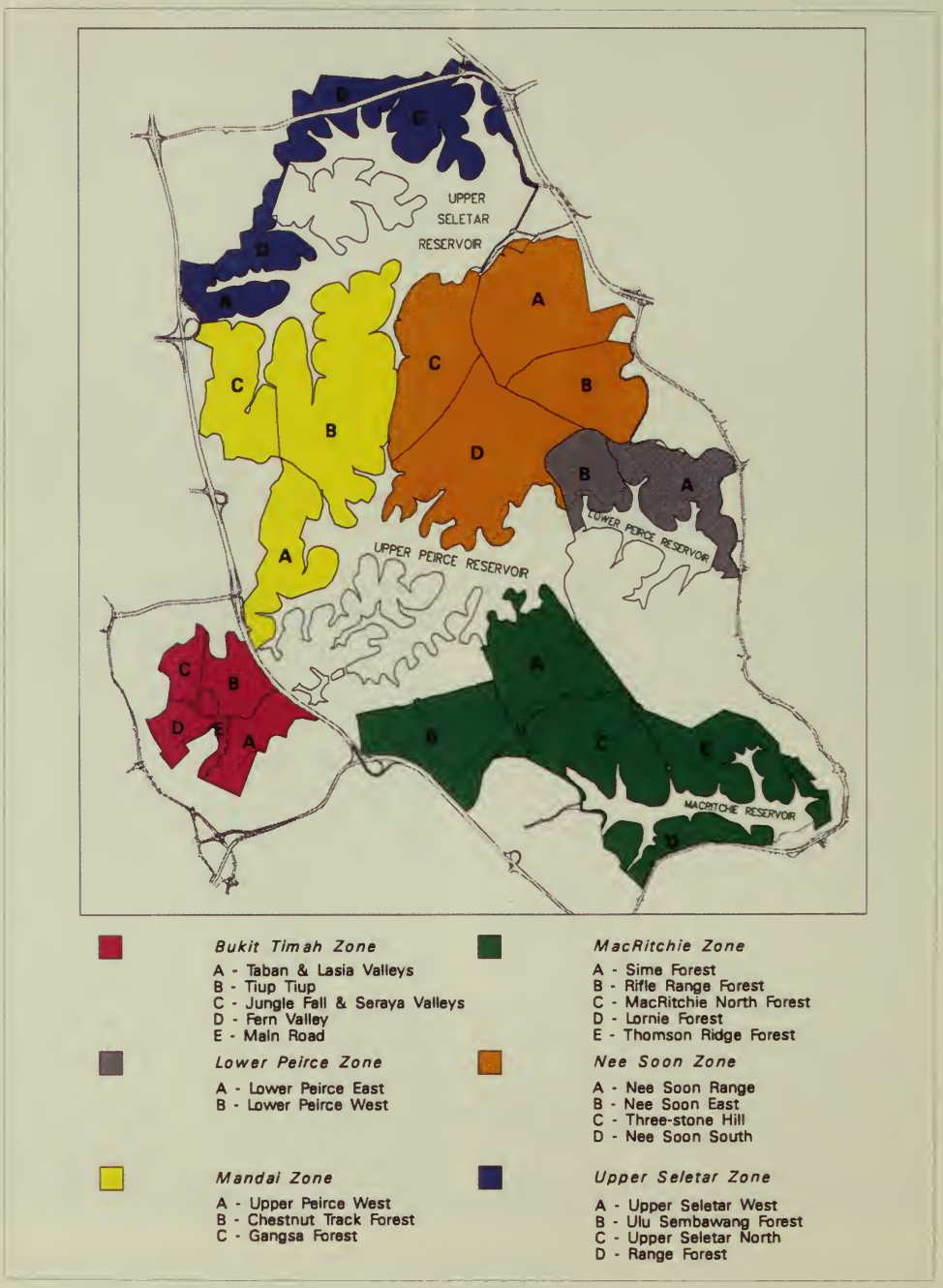


Figure 1. The zones and sectors surveyed in the Nature Reserves.

Field surveys were conducted for about four years. Each sector received detailed nocturnal coverage over two separate weekends, a few months apart. Additional data collected on personal trips into the Nature Reserves by various individuals were also incorporated. The data were divided into two categories - records within the pre-survey period from 1987 to May 1993 and records within the survey period of June 1993 to July 1997. The combined data provided a better picture of the diversity and distribution of the mammals, reptiles and amphibians.

Nocturnal Surveys

As most of the mammalian, reptilian and amphibian species are active at night, nocturnal surveys were an important component of the survey. The basic nocturnal survey stretched from 1700 hours to 0900 hours the next day. Each sector received nocturnal coverage over one weekend per month (usually Friday evening to Saturday morning, Saturday evening to Sunday morning). After every sector of a particular zone had been covered, field survey moved to another zone before returning for a second round of coverage in the same zone. Hence each sector within a zone was covered over two weekends or four nights. During the first year, a half-night session was also conducted as a reconnaissance before the weekend survey.

Various methods were deployed during each night survey. These included mist-netting, trapping, transect surveys and bat-detecting. A minimum of six participants, including four experienced surveyors, were required at any given time for these methods to be used simultaneously. In practice, however, a team of eight to ten was optimal, especially on good capture nights, when more experienced hands were needed to extract and process the numerous animals caught.

Bat-Detecting

Important information on bats was gathered through the use of a bat-detector, which picks up the ultrasonic echo-locating calls of insectivorous bats. Shirley Pottie was the only researcher who could confidently handle the bat-detector, which was normally utilised during transect surveys. As she left Singapore before the completion of the survey, data on bats were highly biased towards zones that had been covered before her departure, namely MacRitchie and Upper Seletar. In addition, the bat-detector was damaged during the survey, and a less sophisticated alternative was later utilised. Unlike the first, this instrument was not able to record the echo-locating calls for further analysis.

Mist-netting

Mist-nets were deployed to capture bats as their very fine mesh was not easily detected by them, and was gentle on captured animals. About five to nine nets, including at least two high nets, were erected at two pre-selected spots by dusk. The nets were about 2.5 metres high, with lengths of 18, 30 or 42 feet, and denier of 30 or 50. High nets were set up by taping two bamboo poles together to raise the nets to a height of about 6 metres. Pulleys were attached to the top of the poles so that the nets could be raised and lowered like a flag. The remaining nets were set at a low level, from the forest floor to a height of over 2.5 metres. On exceptional occasions, "triple-storey" nets were tried, where three poles were taped together to allow the nets to reach a height of about 8 metres. The nets were left open from about 1830 hours to 0730 hours the next day. They were checked regularly, especially during peak activity periods.

A harp trap for bats was also used a few times but failed to capture anything. This type of trap has been used successfully to capture insectivorous bats worldwide. The lack of success could be due to insufficient traps.

Trapping

Small spring-door traps were utilised for small mammals like treeshrews, rats and squirrels. Apart from these target species, several terrapins, three palm civets and a monkey were also caught. About 50 traps were placed by NParks' staff along a pre-selected transect, at 20-metre intervals, a few days prior to each weekend survey. These were left open to allow animals to accept them as part of their habitat.

Banana and papaya were the main baits used, although jackfruit, pineapple, apple, grape, durian seed, sweet potato, bread, dried cuttlefish, salted fish and soap were also tried. Banana proved to be the most effective bait, but jackfruit and bread provided good results as well. During the weekend surveys, traps were baited on Friday evenings, and were checked and re-baited on Saturday mornings. A second team would then check and re-bait the traps on Saturday evenings, and a final check was made on Sunday mornings. Captured animals were carefully processed before release.

Larger traps for animals like palm civets, leopard cats and mousedeer were also utilised a couple of times but were generally non-productive. Pitfall traps for smaller species were used in association with drift fences.

Transect Surveys and Casual Sightings

Many species could not be captured by the above-mentioned methods. For these, transect surveys were deployed. At each sector, two transects, of 1 to 3 kilometres each, were covered on foot by one to four surveyors. A transect was usually covered after dusk and at around midnight. Rocks, buttresses and streams were thoroughly scanned with powerful spotlights for animals. Casual sightings by surveyors around the Base Camp also provided valuable data. Attention was given especially to streams and other water-bodies in the area.

Road-kill surveys

Motorable roads bordering or running through the Nature Reserves lend themselves well to road-kill surveys. Much information on reptiles, especially snakes, was gathered through this method. The roads were surveyed either on foot or bicycle. Road-kill surveys were carried out for the service roads to Bukit Kalang Service Reservoir, Upper Peirce Reservoir Park and Upper Seletar Reservoir Park, end of Sime Road, Rifle Range Road, Old Upper Thomson Road, Mandai Lake Road, Mandai Track 15, Old Mandai Road and Jalan Ulu Sembawang. It should be noted that data on snakes were biased towards sectors with heavily used roads like Old Upper Thomson Road. Obviously, sectors without any roads would have no data from road-kill surveys.

Identification

The main references used for identification of species were:

Mammals - Medway (1983), Payne *et al.* (1985), Corbet & Hill (1992) and Lekagul & McNeely (1988).
Reptiles - Tweedie (1983), Lim & Lee (1989), Lim & Lim (1992), Inger & Tan (1996), and Manthey & Grossman (1997).
Amphibians - Berry (1975), Lim & Lim (1992), Inger & Stuebing (1989) and Manthey & Grossman (1997).

To aid identification and for record purposes, photographs of rarer species were taken, usually with slide film. Where necessary, descriptions and measurements were also recorded.

Results

For the pre-survey period, 94 indigenous species were recorded - 17 mammals, 57 reptiles and 20 amphibians. The survey period yielded a total of 131 indigenous species - 42 mammals, 66 reptiles and 23 amphibians. Combining both periods, i.e., between 1987 and July 1997, gave a total of 141 indigenous species (44 mammals, 72 reptiles and 25 amphibians).

A total of ten indigenous species from the pre-survey period were not recorded in the survey period - two mammals, six reptiles and two amphibians. In contrast, 54 species from the survey period were not recorded in the pre-survey period - 27 mammals, 21 reptiles, and six amphibians. This indicates the effectiveness of a deliberate survey in establishing an inventory of species over casual observations in the pre-survey period.

Bukit Timah, Nee Soon and MacRitchie scored well in terms of overall diversity of indigenous species (Figure 2). Bukit Timah, especially, stood out from the other zones with 98 species compared to a mean of 80 and mammal diversity was highest, 28 species compared to a mean of 23. Lower Peirce had only 18 species while the other zones ranged from 22 to 24 species. The mean reptile diversity was 41 species. The most diverse zones for reptiles were Bukit Timah (51 species) and MacRitchie (50 species), but Nee Soon and Lower Peirce were not far behind, with 46 species each. Reptile diversity was markedly lower at Mandai (14 species). Amphibian diversity was highest at Nee Soon (21 species) and Bukit Timah (19 species) - the mean diversity was 16 species.

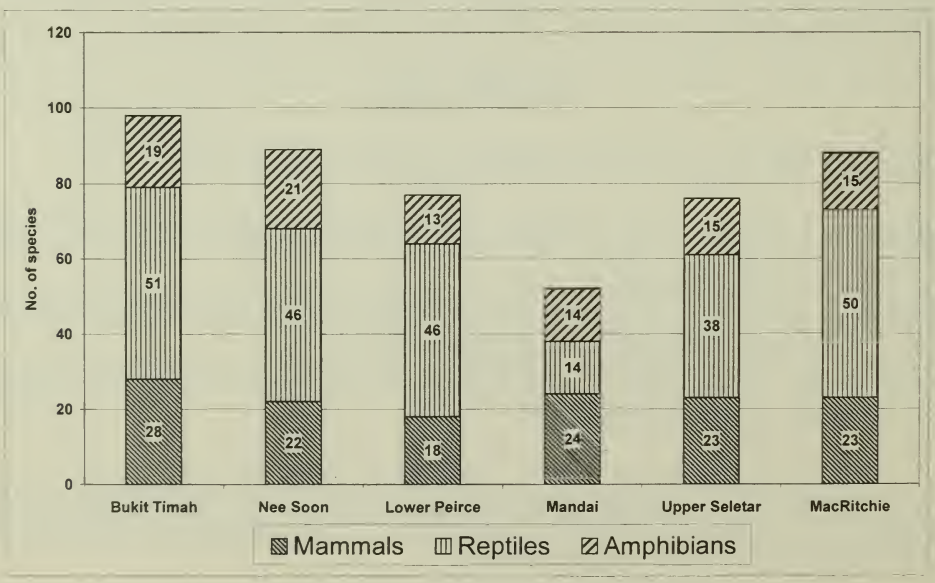


Figure 2. Species diversity according to zones in the Nature Reserves.

A total of 80 species have populations that are threatened (50 endangered, 11 rare, 17 uncommon and two indeterminate). From Figure 3, it is obvious that the key refuges for threatened species are Bukit Timah (50 species), Nee Soon (46 species) and MacRitchie (40 species).

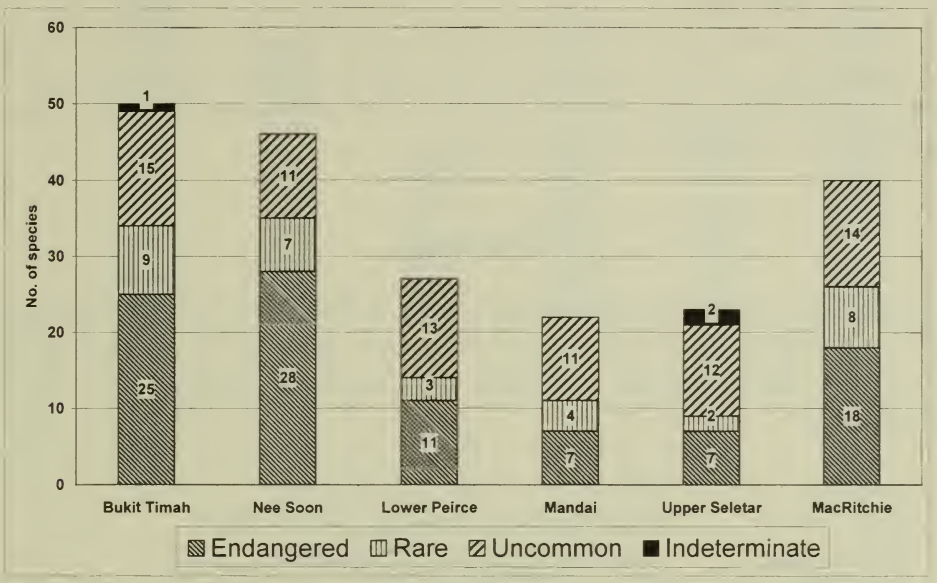


Figure 3. Number of threatened species according to zones in the Nature Reserves.

The following terminology is used in this paper:

- **Endemic subspecies** : Subspecies confined to Singapore, i.e., found nowhere else in the world
- **Localized species** : Species that are presently found in a particular zone and nowhere else in Singapore
- **Discovery** : Species recorded for the first time in Singapore within the survey period
- **Rediscovery** : Species recorded within the survey period previously not seen in the past 30 years
- **Recent Discovery** : Species recorded for the first time in Singapore within the pre-survey period or a species recorded for the first time in Singapore during the survey period but from outside the Nature Reserves
- **Recent Rediscovery** : Species recorded within the pre-survey period that has not been seen in the past 30 years, or a species recorded in the survey period but from outside the Nature Reserves, which has not been seen in the past 30 years.

Between 1987 and 1997, there were 10 discoveries (four mammals, three reptiles and three amphibians), four recent discoveries (two reptiles and two amphibians), 13 rediscoveries (nine mammals, three reptiles and one amphibian) and 10 recent rediscoveries (four mammals, five reptiles and one amphibian).

The following section deals with every indigenous mammal, reptile and amphibian species recorded from 1987 to 1998. A few exotic feral species (marked *) are also mentioned as they have significant established populations within the Nature Reserves.

Mammals

Nomenclature for mammals follows Corbet & Hill (1992). For most species, the following conventions and criteria are adopted in describing the abundance of mammals (numbers indicate known population size in Singapore):

- **Endangered** : Occurring in very low numbers (< 30)
- **Rare** : Occurring in low numbers (30–59)
- **Uncommon** : Occurring in moderate numbers (60–99)
- **Fairly Common** : Occurring in high numbers (100–199)
- **Common** : Occurring in very high numbers (> 199)

Only 17 indigenous mammals were recorded in the pre-survey period, while 42 were recorded in the survey period making a total of 44 indigenous species recorded from 1987 to 1997, of which 21 species are forest dwellers (48%) and 23 are not dependent on the forest. Twenty-one species (48%) are restricted to the Nature Reserves.

Bukit Timah, Mandai, MacRitchie and Nee Soon are key sanctuaries for threatened mammal species (Figure 4). Twenty-six species (59%) are threatened with extinction - 19 endangered, five uncommon and two indeterminate. These include three endemic subspecies - *Tragulus javanicus fulviventer*, *Ratufa affinis affinis* and *Rhinosciurus laticaudatus leo*. The last species is in fact found only in Bukit Timah. In addition, seven other localized species also have threatened populations - *Penthetor lucasi*, *Emballonura monticola, Nycteris tragata*, *Tylonycteris pachypus*, *Cheiromeles torquatus*, *Iomys horsfieldii* and *Hylopetes spadiceus*. Each of these highly endangered species was recorded from only one zone. The distribution of endangered and rare mammals is mapped out in Figure 5.

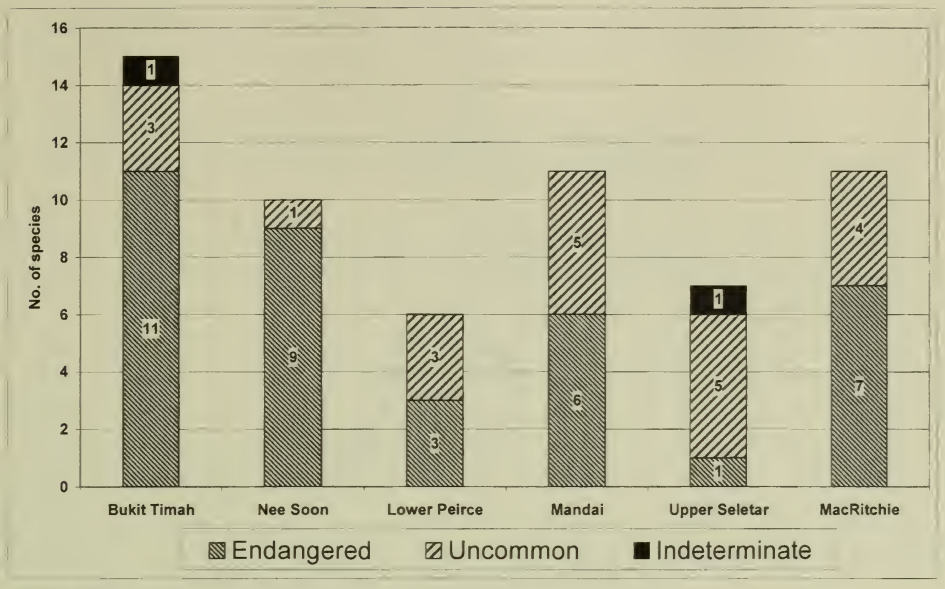


Figure 4. Number of threatened mammal species in the Nature Reserves.

ORDER **PHOLIDOTA**
Family **Manidae**

1. *Manis javanica* Desmarest, 1835
   Sunda Pangolin, Malayan Pangolin, Scaly Anteater

There were 16 records of *M. javanica* - five from the pre-survey period and 11 from the survey period. It is fairly well distributed but MacRitchie is the most important area (8 records). This species has often been poached for its meat, and in recent years, its population outside the Nature Reserves has declined drastically. The future of *M. javanica* may depend on the survival of the population existing within the Nature Reserves. We are listing it as endangered.

ORDER **INSECTIVORA**
Family **Soricidae**

2. *Suncus murinus murinus* (Linnaeus, 1766)
   House Shrew

There were only three records of this shrew, all from Upper Seletar. This

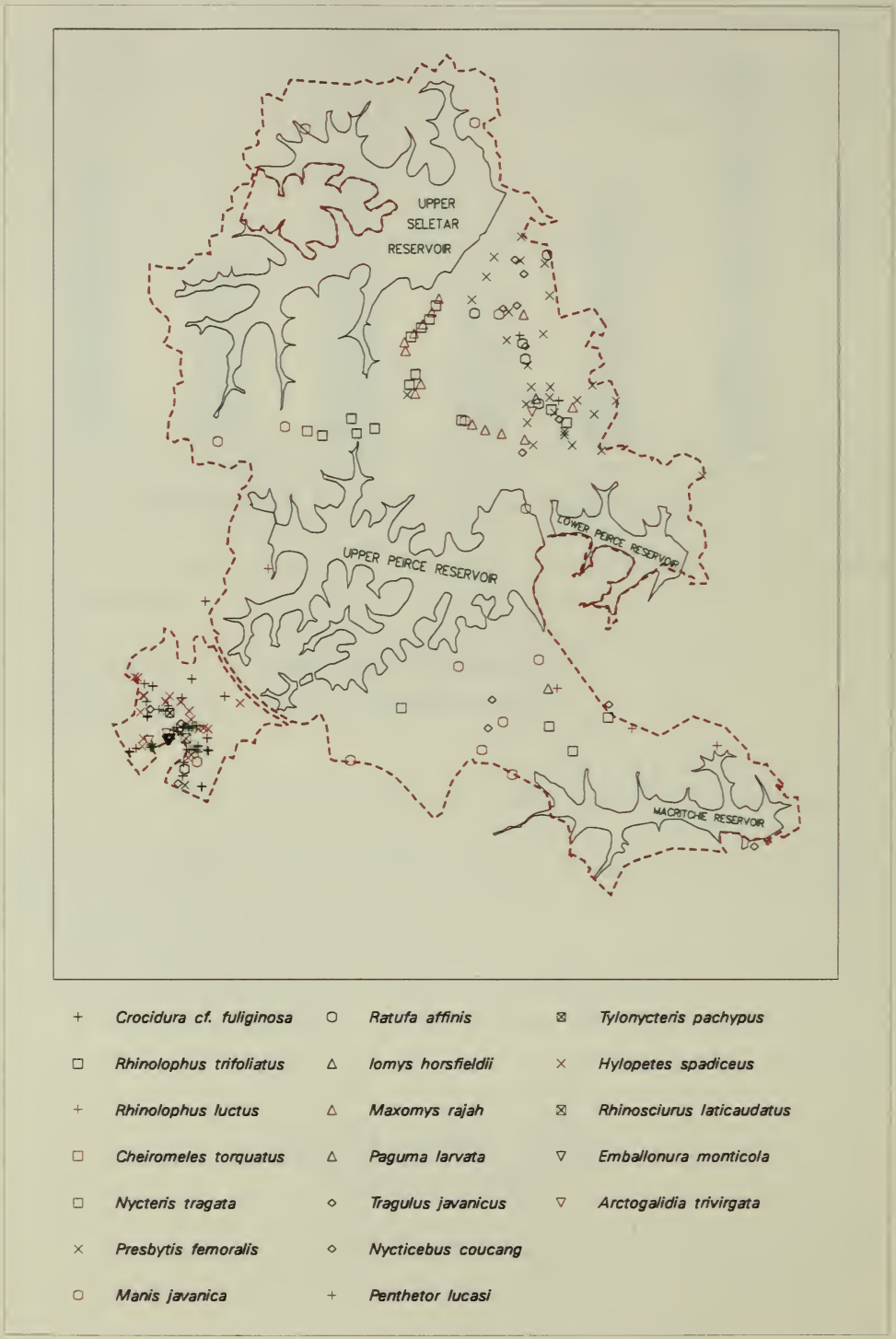


Figure 5. Distribution of endangered and rare mammals.

is not surprising as it is more commonly found in urban and suburban areas.

3. *Crocidura* cf. *fuliginosa malayana* Robinson & Kloss, 1911
South-east Asian White-toothed Shrew, Common White-toothed Shrew

Murphy (1973) first recorded *C. fuliginosa* at Bukit Timah - specimens were found in pitfall traps laid out for insects - but there had been no further records until the survey. Pitfall traps laid out by NParks resulted in 21 widely distributed records at Bukit Timah, and five each at Nee Soon and Mandai (at a proposed "faunal link", just on the outskirts of CCNR). Medway (1983) stated that *C. fuliginosa* occurs "in all habitats from montane to lowland forest, scrub, grass and cultivated land, and including caves." It is postulated that the species will be found to be more widespread in Singapore, if pitfall trapping is carried out in areas away from the Nature Reserves. At present however, this species has to be treated as endangered and confined to the Nature Reserves and its vicinity.

ORDER **SCANDENTIA**
Family **Tupaiidae**

4. *Tupaia glis ferruginea* Raffles, 1821
Common Treeshrew

This is the dominant diurnal mammal of the forest floor. The 702 records from the survey period alone indicate it is probably overly abundant within the Nature Reserves. Bukit Timah is definitely over-populated with *T. glis*, where it accounted for 70% (323 records) of all trappings. This species is also common in wooded areas outside the Nature Reserves.

ORDER **DERMOPTERA**
Family **Cynocephalidae**

5. *Cynocephalus variegatus peninsulae* (Thomas, 1908)
Malayan Colugo, Malayan Flying Lemur

Harrison (1966) and Medway (1983) reported that *C. variegatus* was common in Singapore, but Yang *et al.* (1990) listed it as uncommon, and Wee (1992) even considered it to be rare. Based on the current data, the authors consider this species as fairly common. There were 22 records from the pre-survey period and 95 records from the survey period. Although

widespread in distribution, the largest populations are apparently in Bukit Timah (where it is quite easily spotted) and MacRitchie.

ORDER **CHIROPTERA**
Family **Pteropodidae**

6. *Pteropus vampyrus malaccensis* Andersen, 1908
   Large Flying Fox, Malayan Flying Fox

This species is believed to be no longer resident in Singapore, as no permanent roosts are currently known to exist. Furthermore, numbers fluctuate through the year and at times, the species is absent. All recent records were probably of visitors from Malaysia. There were 159 records from the pre-survey period, and only 24 from the survey period. The largest bat in the world, *P. vampyrus*, has a wingspan of up to 1.5 metres (Medway, 1983). It is threatened by habitat loss and poaching (especially during the durian flowering season).

7. *Cynopterus brachyotis brachyotis* (Müller, 1838)
   Lesser Dog-faced Fruit Bat, Common Fruit Bat, Malaysian Fruit Bat

This is the dominant fruit bat in the Nature Reserves (670 records from the survey period). It is also the most common and widespread fruit bat in Singapore.

8. *Penthetor lucasi* (Dobson, 1800)
   Dusky Fruit Bat
   Plate 1a

The last record of Singapore's only true forest fruit bat was in 1925, until its rediscovery in 1995 in Bukit Timah where a colony of over 80 individuals was found roosting in a man-made tunnel complex along Cave Path, while a possibly separate population of at least 13 was located at the bottom of Fern Valley. There was a total of 123 records, including females with young.

9. *Eonycteris spelaea* (Dobson, 1871)
   Cave Nectar Bat, Cave Fruit Bat, Dawn Bat

Eonycteris spelaea was last recorded from Singapore in 1924, and Yang *et al.* (1990) listed it as 'indeterminate'. The species was recently rediscovered

in 1990 at Sungei Buloh Nature Park, where three were mist-netted. Throughout the survey, a total of seven bats were mist-netted for the first time in CCNR (MacRitchie, Lower Peirce and Mandai). Outside the Nature Reserves, a roost of over 50 was located at Pandan in 1997 while another of about 370 was found in the Bukit Timah area. Both roosting sites were under expressway flyovers and were quite well lit. Considering the abundance of flowering plants and the great number of flyovers in Singapore, this nectarivorous bat is probably surviving well.

Family **Emballonuridae**

10. *Emballonura monticola monticola* Temminck, 1838
Lesser Sheath-tailed Bat

Pottie (1996) recorded the rediscovery of *E. monticola* in Bukit Timah, where she recorded a maximum of six individuals. *Emballonura monticola* roosts are often rather exposed e.g. hollow logs and rock overhangs. There is no lack of such habitats, especially in Bukit Timah, and it is hoped that future surveys will produce more records of this highly endangered species.

11. *Taphozous saccolaimus crassus* (Blyth, 1844)
Pouched Tomb Bat, Pouch-bearing Bat

Listed as indeterminate by Yang *et al.* (1990), this bat was recently rediscovered at Pulau Ubin in 1993. It is common and found throughout Singapore - 238 records were obtained during the survey period, including the first confirmed record of the species from the Nature Reserves.

Family **Nycteridae**

12. *Nycteris tragata* (Andersen, 1912)
Hollow-faced Bat
Plate 1b

The first and only record of this species was made in 1993, when a pair was found roosting in a culvert at Rifle Range Forest (MacRitchie). They were caught and taken to the National University of Singapore for processing. Unfortunately, the female died and was deposited as a voucher specimen at the Zoological Reference Collection. The male was released at the point of capture but has not been recorded again.

Family **Rhinolophidae**

13. *Rhinolophus trifoliatus trifoliatus* Temminck, 1834
Trefoil Horseshoe Bat
Plate 1c

Last recorded from Singapore in the 1930s, and classified as indeterminate in status by Yang *et al.* (1990), *R. trifoliatus* was rediscovered in 1994 at MacRitchie, where four were recorded. A larger population of 14 was later located at Nee Soon and Mandai.

14. *Rhinolophus luctus morio* Gray, 1842
Great Woolly Horseshoe Bat, Great Eastern Horseshoe Bat
Plate 1d

An identified rhinolophid bat was detected through its call at MacRitchie (three records) and Mandai (one record) during the survey period. These were probably the same records that Pottie (1996) attributed to *R. luctus*. Although a true forest bat, it was also recorded at Fairy Point Hill, Changi, a suburban area (Pottie, 1996).

15. *Rhinolophus lepidus* Blyth, 1844
Blyth's Horseshoe Bat

In Peninsular Malaysia, this species was formerly known as *R. refulgens*, the Glossy Horseshoe Bat, a name which is now considered a synonym of *R. lepidus*. This species is a discovery for Singapore, the first official record being in 1994 at Upper Peirce West (Mandai). Pottie (1996) had, however, recorded it earlier at Bukit Timah in 1993 or 1994 (S.A. Pottie, *pers. comm.*). But since no details of the record were published, it was not officially accepted as the first record. *Rhinolophus lepidus* is widespread in the Nature Reserves, with a big population of at least 350 at Bukit Timah. Though new to Singapore, we consider the species to be fairly common, as there were a minimum of 555 records.

Family **Vespertilionidae**

16. *Myotis muricola muricola* (Gray, 1846)
Whiskered Myotis, Whiskered Bat

This bat is the most common species along roads and tracks within the

forest. It is widespread and Pottie (1996) recorded it in all habitats except the city.

17. *Myotis adversus* (Horsfield, 1824)
Grey Large-footed Myotis

Harrison (1966) implied that *M. adversus* was rare in Singapore (based only on an old record), and Medway (1983) regarded the species as rare in Peninsular Malaysia. This is amazing, as Pottie (1996) found it to be common in Singapore, being recorded island-wide over many fresh and brackish water-bodies. During the survey, the species was mostly found over reservoirs and adjacent channels (156 records).

18. *Scotophilus kuhlii castaneus* Gray, 1838
Lesser Asiatic Yellow House Bat

This is the commonest insectivorous bat over the forest canopy. Pottie (1996) found many roosts on the rooftops of houses and Housing Development Board (HDB) apartment blocks all over Singapore, and reported it as the commonest microchiropteran in Singapore.

19. *Tylonycteris pachypus pachypus* (Temminck, 1840)
Lesser Bamboo Bat

Pottie (1996) listed *T. pachypus* as extinct but a single bat was mist-netted in 1997, just below the Summit at Bukit Timah. This is the only record since Chasen (1925) and constituted the rediscovery of the species.

20. *Tylonycteris robustula robustula* Thomas, 1915
Greater Bamboo Bat, Greater Flat-headed Bat

There were only 34 records of this species during the survey but it is fairly common and widespread in Singapore. At dusk, it is easily observed hawking for insects with *Scotophilus kuhlii*. Like *T. pachypus*, this species roosts in the internodes of bamboo.

21. ?*Pipistrellus* sp.
Pipistrelle A

An unidentified bat was observed foraging high over open areas (Bukit Timah, Mandai, Upper Seletar and MacRitchie). Pottie (1996) suggested it to be a vespertilionid, and possibly *P. javanicus*, the Javan Pipistrelle - all

other vespertilionids known to have occurred in Singapore were ruled out. This species is tentatively designated as Pipistrelle A, but it is possible that it is a previously unrecorded species for Singapore. This is an uncommon but widespread species.

Family **Molossidae**

22. *Cheiromeles torquatus torquatus* Horsfield, 1824
Naked Bat, Hairless Bat

Cheiromeles torquatus was last recorded in 1979 in a derelict house near Braddell Road (Anon, 1979). The only record since then was of a flock of five over Chestnut Track Forest (Mandai) in 1995. Although found foraging over the forest, this flock could have been roosting outside the Nature Reserves. At present, however, we consider the species as being confined to Mandai, and endangered in status.

ORDER **PRIMATES**

Family **Loridae**

23. *Nycticebus coucang coucang* (Boddaert, 1785)
Slow Loris

Although recorded from Bukit Timah and MacRitchie during the pre-survey period, both records of *N. coucang* were possibly of escapees. The species has also been recorded in 1993 and 1995 at Pulau Tekong (Senin, *pers. comm.*) and is therefore considered extant in Singapore, though highly endangered. There has also been an unconfirmed record from Nee Soon in 1997 (S. Chan, *pers. comm.*).

Family **Cercopithecidae**

24. *Macaca fascicularis fascicularis* (Raffles, 1821)
Long-tailed Macaque, Crab-eating Macaque

Perhaps the most well-known mammal of the Nature Reserves, it is abundant - 1,415 records in the survey period alone - but the records probably involved about 850 individuals, based on maximum counts of troops. It is estimated that about 34 separate troops were encountered during the survey.

25. *Presbytis femoralis femoralis* (Martin, 1838)
Banded Leaf Monkey, Banded Langur

This subspecies is highly endangered, as it is found only in Singapore and South Johor. Locally, with its recent extirpation in Bukit Timah in 1987 (Yang & Lua, 1988), *P. f. femoralis* is now confined to Nee Soon and Lower Peirce. There were a total of 257 records from 1987 to June 1997, but these involved a high degree of duplication. It is suspected that there are only two or three troops, with a total of 18 to 23 individuals. The largest troop, of at least 10 individuals, inhabits the main swamp forest at Nee Soon Range Forest. A second troop moves between Nee Soon East and Lower Peirce West, comprising at least seven individuals. A troop of at least five individuals was reported by NParks staff at Lower Peirce East - this might be a previously unknown troop as it was quite a distance from the other troops. A lone individual was also seen at Three-Stone Hill.

ORDER **CARNIVORA**

Family **Canidae**

26. *Canis familiaris* Linnaeus, 1758
Domestic Dog

Feral dogs were probably more common in the past when villages abounded at the edge of the Nature Reserves. There were only six records during the survey but many other records were probably not reported. Although the population within the Nature Reserves is not substantial, the presence of even a few *C. familiaris* poses a threat to endangered species like *Tragulus javanicus* and *Paguma larvata*. All known populations of this unwelcome species should be removed from the Nature Reserves.

Family **Viverridae**

27. *Paradoxurus hermaphroditus musanga* (Raffles, 1821)
Common Palm Civet, Toddy Cat

There were five records from the survey period - all from the fringes of CCNR (Mandai, Upper Seletar and Lower Peirce), in the vicinity of remnant agricultural habitat. Yang *et al.* (1990) listed this species as common, but the authors are of the opinion that it is now uncommon in Singapore.

28. *Paguma larvata jourdainii* (Gray, 1837)
Masked Palm Civet

Chasen (1924) doubted the record of Singapore specimens of *P. larvata* by Flower (1900). However, based on a record in 1993, at MacRitchie, and another in 1990, at Pulau Tekong (Vasantha, *pers. comm.*), we are listing this species as a possible resident, and the record at MacRitchie, a rediscovery.

29. *Arctogalidia trivirgata sumatrana* Lyon, 1908
Small-toothed Palm Civet, Three-striped Palm Civet

Yang *et al.* (1990) listed this species as indeterminate as there were no recent records since Chasen (1924). Two examples were confirmed from Nee Soon in 1997, after the survey period (S.H. Yeo, *pers. comm.*). During the survey period, there were also two records of an arboreal civet, probably involving the same individual, during night surveys at Bukit Timah. This was believed to be *A. trivirgata*. It was also heard calling incessantly, sounding like *Sundasciurus tenuis*, but much louder and exaggerated.

30. *Viverra tangalunga tangalunga* Gray 1832
Malay Civet

There was an unconfirmed record of this large civet in the early 1990s, at Upper Seletar (Vasantha, *pers. comm.*). If this species still exists, Mandai and Upper Seletar are the most likely zones for future records. *Viverra tangalunga*, has also been reported at Pulau Tekong (Lim, 1991a; Sivasothi, 1994), but the authors believe that might have been a misidentified *V. zibetha*.

ORDER **ARTIODACTYLA**
Family **Tragulidae**

31. *Tragulus javanicus fulviventer* Gray, 1836
Lesser Mousedeer

This subspecies is endemic to Singapore, and internationally endangered. There were five records from the pre-survey period - one from Bukit Timah and two each from Nee Soon and MacRitchie. During the survey period, five records were noted in Nee Soon, while only one each was obtained at Bukit Timah and MacRitchie.

Family **Cervidae**

32. *Cervus unicolor equinus* Cuvier, 1823
Sambar, Sambhur

Natural populations of *C. unicolor* apparently died out decades ago, but a few have been reported from Upper Seletar since the 1970s, including three records from the survey period. These are believed to have been escapees from the nearby Singapore Zoological Gardens or Night Safari. A small feral herd of perhaps about 10 to 15 animals exists at Upper Seletar (Vasantha & T.M. Leong, *pers. comm.*)

33. *Muntiacus muntjak peninsulae* Lydekker, 1915
Common Barking Deer

A single record of *M. muntjak* was obtained from Chestnut Track Forest (Mandai). This might have been one of two reported escapees from the Night Safari (Vasantha, *pers. comm.*), as the species is believed to be extinct (Yang *et al.*, 1990). However, the possible existence of a small remnant population at Mandai should not be ruled out.

ORDER **RODENTIA**
Family **Sciuridae**

34. *Ratufa affinis affinis* (Raffles, 1821)
Cream-coloured Giant Squirrel, Common Giant Squirrel, Pale Giant Squirrel

Another endemic subspecies, *R. a. affinis* is highly endangered and threatened with extinction. Except for a single record from Bukit Timah in 1990, it is confined to Nee Soon, where only four examples (one pair and two individuals) were confirmed in the survey period (all 22 CCNR records from 1987 to June 1997 are believed to involve the same animals).

35. *Callosciurus notatus singapurensis* Robinson, 1916
Plantain Squirrel, Common Red-bellied Squirrel

Although common everywhere, *C. n. singapurensis* is actually endemic to Singapore. It is our only endemic subspecies that is currently not threatened. It is found in forested areas as well as suburban gardens, parks and even on wayside trees. A total of 425 individuals were recorded during the survey period.

36. *Sundasciurus tenuis tenuis* (Horsfield, 1823)
Slender Squirrel

This is the most abundant rodent in the Nature Reserves - 763 were recorded in the survey period alone. The only known sustainable population outside the Nature Reserves is centred at the Botanic Gardens' Rain Forest and Tyersall Woods.

37. *Rhinosciurus laticaudatus leo* Thomas & Wroughton, 1909
Shrew-faced Ground Squirrel

Confined to Bukit Timah, this endemic subspecies is threatened with extinction. The only recent record was in 1989 and none were confirmed during the survey period. This species could be a victim of competition from the abundant *Tupaia glis*.

Family **Pteromyidae**

38. *Iomys horsfieldii davisoni* (Thomas, 1886)
Horsfield's Flying Squirrel,

Chasen (1925) recorded *I. horsfieldii* from Kranji and Bukit Timah. However, the two specimens from Kranji, deposited at the Zoological Reference Collection, are misidentified. This leaves the single specimen from Bukit Timah as the only previous record of the species. *Iomys horsfieldii* was, however, rediscovered in 1995, when a pair was observed at Nee Soon East. This was the first record of the species from CCNR.

39. *Hylopetes spadiceus* (Blyth, 1847)
Red-cheeked Flying Squirrel
Plate 2

This species was only discovered in 1996 in Bukit Timah. The existence of *H. spadiceus* has perhaps been overlooked, due to its small size and a lack of nocturnal surveys in Singapore over the past few decades. Twenty-four records were obtained during the survey period and a small but apparently viable population exists within Bukit Timah. There was also a report in 1990 of a small flying squirrel at Taban Valley, Bukit Timah (M.N. Jumaat, *pers. comm.*), which is now believed to have been *H. spadiceus*. During the survey period, a pair was clearly observed at its nest hole about 2 m above the ground. The local animals have white stockings, a characteristic not

found in any Malaysian flying squirrel. This indicates a possible undescribed subspecies endemic to Singapore. This flying squirrel gives a short, high-pitched shriek as it moves around the forest.

Family **Muridae**

40. *Rattus rattus diardii* (Jentinck, 1880)
House Rat, Roof Rat

There were four records of this familiar rat - one from the Summit of Bukit Timah, and two in scrubland at Upper Seletar. *Rattus rattus* is more commonly found in urban and suburban areas, and the Bukit Timah example probably reached the Summit by way of the access road. A possible example was, however, trapped at Seraya Valley under primary forest, but it escaped during processing, and its identity could not be positively established.

41. *Rattus tiomanicus jalorensis* (Bonhote, 1903)
Malaysian Wood Rat, Malaysian Field Rat

Only 19 examples were recorded (three in the pre-survey period and 16 in the survey period), but this species is believed to be more prevalent outside rain forest. Future surveys, especially in forest fringe, scrub and back mangrove, should produce more records for Singapore. At Bukit Timah, an example was known to have gnawed through a Chengal-timber door.

42. *Rattus exulans concolor* (Blyth, 1859)
Polynesian Rat

Commonly found in urban and suburban areas, *R. exulans* was recorded only once from Upper Seletar in scrubland.

43. *Rattus annandalei bullatus* (Lyon, 1908)
Annandale's Rat, Singapore Rat

Rattus annandalei is the most common nocturnal mammal of the forest floor (310 records in the survey period). Considering that Harrison (1966) and Medway (1983) were of the opinion that its natural habitat is secondary forest and scrub, the abundance of *R. annandalei* (even in primary vegetation) is cause for concern. The population at Bukit Timah (107 records) is especially worrying with respect to competition with spiny rats.

44. *Maxomys rajah pellax* (Miller, 1900)
Brown Spiny Rat, Rajah Rat

New to Singapore, *M. rajah* was first recorded in 1995 at Three-Stone Hill (Nee Soon), where two were trapped. Subsequently, a total of 19 were trapped from all sectors in Nee Soon, but mainly from Three-Stone Hill. There is probably a viable but nonetheless endangered population. This murid has not been confirmed outside Nee Soon though juveniles of a spiny rat were caught both at Lower Peirce and Mandai but these could not be identified to species, as juveniles of *M. rajah* and *M. surifer* look alike. The two records outside Nee Soon are tentatively placed under *M. rajah*, the only spiny rat confirmed for CCNR thus far.

45. *Maxomys surifer leonis* (Robinson & Kloss, 1911)
Red Spiny Rat

The last records of this endemic subspecies were in 1968 from Bukit Timah (Murphy, 1973) but no specimens were kept and the identification is doubtful. A spiny rat was observed once in the field at Bukit Timah during the survey period, but could not be identified to species. With the discovery of *M. rajah* at Nee Soon, this spiny rat could, however, not be assumed to be *M. surifer.*

Reptiles

Nomenclature for reptiles generally follows Lim & Lim (1992) and Denzer & Manthey (1991). For most species, the following convention and criteria are used to describe the abundance of reptiles (numbers indicate known population size in Singapore):

- **Endangered** : Occurring in very low numbers (< 10)
- **Rare** : Occurring in low numbers (10–19)
- **Uncommon** : Occurring in moderate numbers (20–29)
- **Fairly Common** : Occurring in high numbers (30–39)
- **Common** : Occurring in very high numbers (> 39)

As most reptiles are not easily detectable, it is difficult to designate a reptile as extinct, even if there have been no records for a long period of time. For this reason, not much data on extinct reptiles is available. From Lim & Lim (1992), it is, however, assumed that there are no recent records (at that time) for 33 terrestrial species (32%) not covered in its main text.

During the pre-survey period, 57 indigenous species were recorded, while the survey period produced 65 species making a total of 72 for the period 1987 to July 1997, of which 35 are forest species (49%) and 37 are not true forest dwellers. Twenty-eight species (39%) are confined to the Nature Reserves.

Bukit Timah, Nee Soon, MacRitchie and Lower Peirce are the four most important zones for threatened reptile species (Figure 6). Forty species (56%) are considered to be threatened, 24 endangered, seven rare and nine uncommon. These include nine localized species - *Ahaetulla fasciolata*, *Ophites subcinctus*, *Psammodynastes pictus*, *Rhadophis subminiatus*, *Xenochrophis piscator*, *Xenochrophis trianguligerus*, *Zaocys fuscus*, *Lygosoma* sp. and *Cyrtodactylus* cf. *consobrinus*. The distribution of endangered and rare reptiles is mapped in Figures 7 and 8.

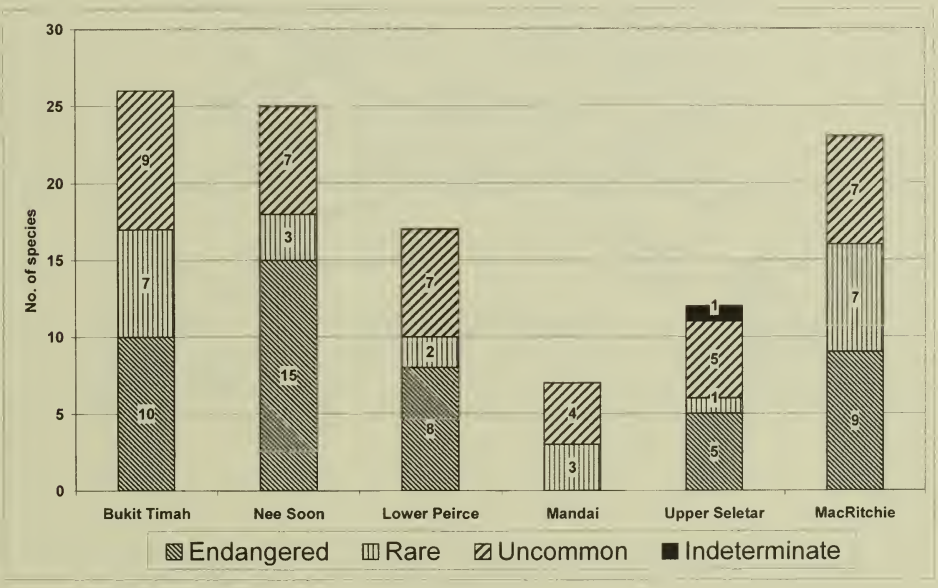


Figure 6. Number of threatened reptile species in the Nature Reserves.

ORDER **SQUAMATA**
Family **Boidae**

1. *Python reticulatus* (Schneider, 1801)
   Reticulated Python

The world's longest snake (up to 10 m) is both common and widespread in

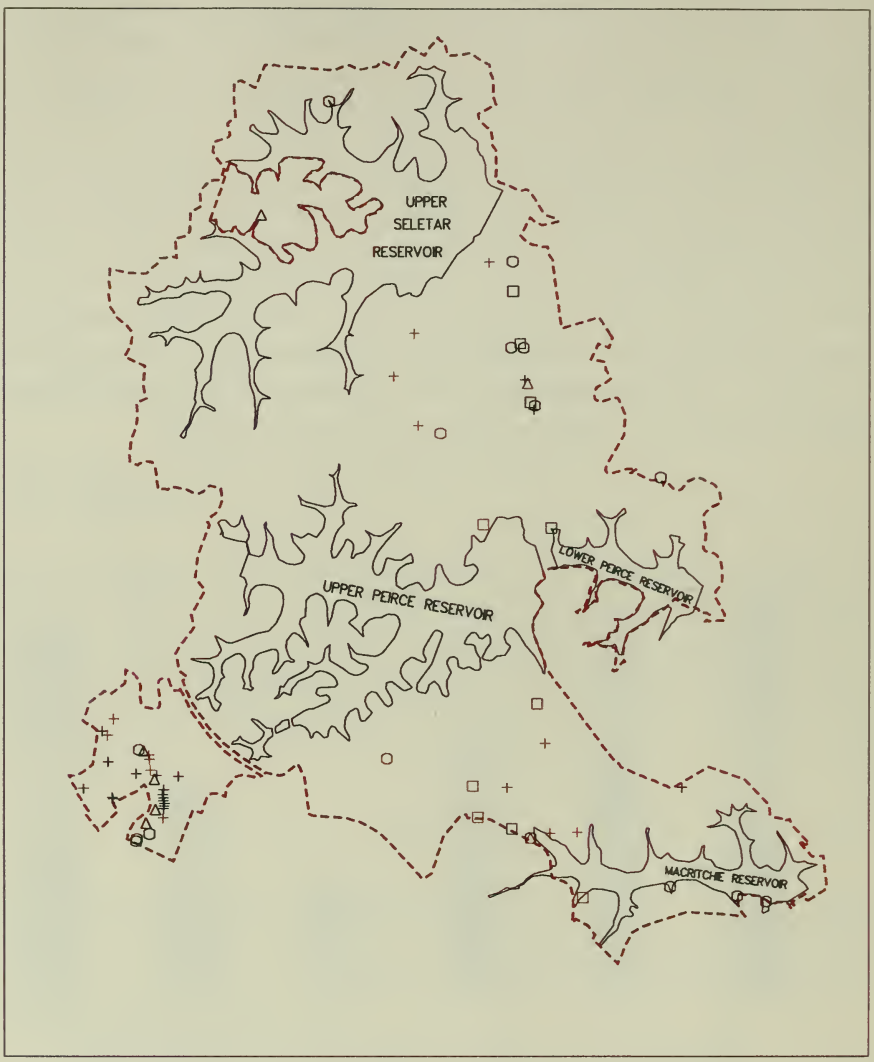
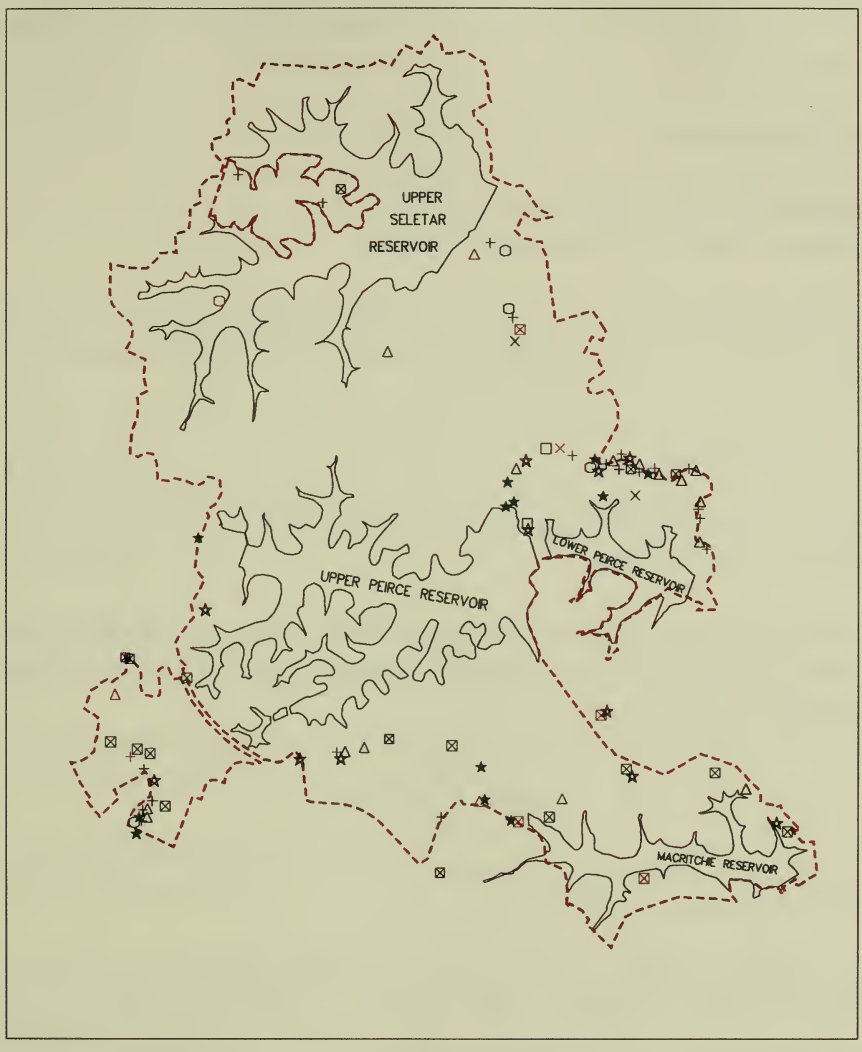


Figure 7. Distribution of endangered and rare reptiles (excluding snakes).



+ *Calamaria lumbricoidea*	△ *Gonyosoma oxycephala*	○ *Psammodynastes pictus*
☆ *Liopeltis baliodeirus*	△ *Oligodon signatus*	× *Zaocys fuscus*
+ *Chrysopelea pelias*	⊠ *Boiga cynodon*	× *Ophites subcinctus*
□ *Dryophiops rubescens*	⊠ *Ophiophagus hannah*	× *Boiga jaspidea*
★ *Boiga dendrophila*	⊠ *Tropidolaemus wagleri*	+ *Ahaetulla fasciolata*
□ *Xenochrophis trianguligerus*	○ *Dryocalamus subannulatus*	
△ *Xenochrophis maculatus*	○ *Rhadophis subminiatus*	

Figure 8. Distribution of endangered and rare snakes.

Singapore. It was recorded from all zones in the Nature Reserves. This species has learnt to use our drainage and sewerage systems to its advantage. It is actually useful in helping to keep the rodent pest population in check.

Family Xenopeltidae

2. *Xenopeltis unicolor* Reinwardt, 1827
Sunbeam Snake, Iridescent Earth Snake

A medium-sized snake, *X. unicolor* is actually quite harmless. Although there were only nine records from the survey, it is believed to be fairly common, as it is an obscure burrower.

Family Typhlopidae

3. *Ramphotyphlops braminus* (Daudin, 1803)
Common Blind Snake

Another burrowing species, *R. braminus* is commonly found in gardens and parks and presumably in the Nature Reserves as well. Only one example was recorded in the survey.

Family **Colubridae**

4. *Ahaetulla fasciolata* (Fischer, 1885)
Speckled-headed Whip Snake

There was only a single confirmed record of this endangered snake from the Nature Reserves (Bukit Timah). A record of one donated to the zoo gave no details of its origin (Lim, 1990a). Due to its arboreal habit and brown colouration, it is easily overlooked.

5. *Ahaetulla prasina* (Boie, 1827)
Oriental Whip Snake

One of the commonest snakes in Singapore, *A. prasina* is also found in gardens and parks. There were a total of 33 records, spread across all zones except Mandai. It is the most frequently recorded snake at Upper Seletar (14 records). This arboreal species is normally camouflaged and when disturbed it moves very swiftly, appearing to flow through the foliage. It preys on lizards and other small creatures.

6. *Boiga cynodon* (Boie, 1827)
   Dog-toothed Cat Snake

This endangered species was found on eight occasions (four within the pre-survey period, and four during the survey). It is arboreal and grows up to 2.5 m in length. A forest dweller, *B. cynodon*, was recently recorded from Pulau Ubin. This was surprising as the forest there is very much degraded, in comparison to the Nature Reserves.

7. *Boiga dendrophila* (Boie, 1827)
   Yellow-ringed Cat Snake, Mangrove Snake

This is one of our most striking snakes. Though rare, *B. dendrophila* is not confined to the rain forest - it has also been found in mangroves. With a maximum length of about 2.5 m, this species should not be handled as it readily bites when provoked. There were a total of 13 records, mostly of live examples.

8. *Boiga jaspidea* (Dumeril, Bibron & Dumeril, 1854)
   Jasper's Cat Snake, Mottled Cat Snake

This endangered species was recorded in the pre-survey period only - once each from Upper Seletar and Lower Peirce.

9. *Calamaria lumbricoidea* Boie, 1827
   Variable Reed Snake

This rare species was recorded ten times in the survey. Because of its burrowing habit, it is not often seen. Like *C. schlegeli* below, it is totally harmless to humans.

10. *Calamaria schlegeli schlegeli* Dumeril, Bibron & Dumeril, 1854
    Pink-headed Reed Snake

A total of 26 records were obtained for this species, mostly from Lower Peirce (11 records) and Bukit Timah (eight records). The first author has also recorded it in 1989 at Holland Woods, outside the Nature Reserves. This indicates that *C. schlegeli* may not be a true forest species. Further records are needed to confirm this.

11. *Chrysopelea paradisi* (Boie, 1827)
    Paradise Tree Snake

This beautiful species, like *C. pelias* below, has been observed to glide from tree to tree. Other than the Nature Reserves, it is also commonly found in gardens and parks. It is known to eat mice, birds and lizards (Lim & Lee, 1989) and the first author has even recorded one with a bat (*Tylonycteris robustula*) in its coils.

12. *Chrysopelea pelias* (Linnaeus, 1758)
Twin-barred Tree Snake

There were 12 records of this attractive, arboreal species, with eight records coming from Lower Peirce. Sadly, except for one live example each at Nee Soon and Bukit Timah, all records were of road-kills. This rare forest species has surprisingly been recorded recently from Pulau Ubin.

13. *Dendrelaphis caudolineatus* (Gray, 1824)
Striped Bronzeback

Although growing up to 2 m, this species is rather inoffensive. Like all bronzebacks, it is arboreal and very agile among the branches, where it hunts for small birds, lizards and frogs (Lim & Lee, 1989). There were a total of 15 records during the survey.

14. *Dendrelaphis formosus* (Boie, 1827)
Elegant Bronzeback

This is possibly the commonest arboreal snake in the Nature Reserves (34 records), and the dominant snake at Lower Peirce (18 records). It has the ability to puff up the anterior part of its body when threatened, thus appearing larger.

15. *Dendrelaphis pictus* (Gmelin, 1788)
Painted Bronzeback

More commonly found in open or lightly wooded areas, *D. pictus* was recorded 12 times in the Nature Reserves. Its diet consists of frogs and lizards.

16. *Dryocalamus subannulatus* (Dumeril, Bibron & Dumeril, 1854)
Saddled Tree Snake, Malayan Bridal Snake
Plate 3a

Dryocalamus subannulatus was recently rediscovered in 1990 when a dead

specimen was found on a road at Lower Peirce. Two live examples were subsequently recorded in 1996 at Nee Soon and Bukit Timah. This slender inoffensive snake can be easily handled.

17. *Dryophiops rubescens* (Gray, 1835)
Keel-bellied Whip Snake

A road-kill of this highly endangered snake was found during the survey period at Lower Peirce. Supposedly a forest species, it has also been recently recorded from Pulau Ubin.

18. *Elaphe flavolineata* (Schlegel, 1837)
Common Racer, Common Malayan Racer

There were only four records of this species, but it is more commonly found in agricultural and other open areas. A large species reaching 2 m, it is terrestrial and feeds on rodents and birds.

19. *Gonyosoma oxycephala* (Boie, 1827)
Red-tailed Racer

This species starts life with a humble olive-brown colour, but is a beautiful green when mature. The tail is brown or red. There were a total of only four records at MacRitchie, Nee Soon and Bukit Timah. It is arboreal and not easily seen as its green coloration blends with the surrounding foliage.

20. *Homalopsis buccata* (Linnaeus, 1758)
Puff-faced Water Snake

With 41 records, *H. buccata* is technically the commonest snake in the Nature Reserves. It is, however, restricted to aquatic habitats, with the largest population at Nee Soon (24 records), where it is the commonest snake. The juvenile has a reddish-orange body, handsomely marked with broad black bands. As it matures, the coloration changes to light brown or grey, with darker bands. Its diet consists of fish and probably frogs.

21. *Liopeltis baliodeirus* (Boie, 1827)
Orange-bellied Ringneck

This rare, harmless species has a light orange underside. Only 11 were recorded, mainly from MacRitchie (five records) and Lower Peirce (four records). It is normally found on low vegetation or on the forest floor.

22. *Macropisthodon rhodomelas* (Boie, 1827)
Blue-necked Keelback

There were 10 records of this frog-eating species. It is fairly common and also occurs in open country and wooded areas.

23. *Oligodon octolineatus* (Schneider, 1801)
Striped Kukri Snake

An attractive and harmless species, this snake is common and widespread in the Nature Reserves (21 records). It is also found in rural areas and perhaps parks and gardens. Lim & Lim (1992) suspected that eggs form a major part of its diet, and during the survey, a pair was observed in a tree hole with large reptilian eggs.

24. *Oligodon signatus* (Günther, 1864)
Barred Kukri Snake

There are only four recent records of the endangered *O. signatus* - two at MacRitchie, and a single example each from Bukit Timah and Nee Soon. Except for the Nee Soon snake, all others were road-kills.

25. *Ophites aulicus* (Linnaeus, 1758)
Common Wolf Snake, House Snake

This is a common snake of suburban and cultivated areas. Its diet consists largely of geckoes. Hence, it is often encountered in or near buildings.

26. *Ophites subcinctus* (Boie, 1827)
Banded Wolf Snake

A road-kill at Lower Peirce in 1988 remains the only recent record of this attractive snake. Inger & Tan (1996) stated that this species never grows beyond 40 cm in length, but the Singapore specimen measured over 49 cm (Lim, 1988).

27. *Psammodynastes pictus* Günther, 1858
Painted Mock Viper

Lim (1991b) noted that *P. pictus* feeds on fish and prawns. The only record in the past decade came from Nee Soon in 1991.

28. *Pseudorhabdion longiceps* (Cantor, 1847)
Dwarf Reed Snake

This tiny snake lives in the leaf litter, under logs and stones, and can even burrow. It is not restricted to forest.

29. *Ptyas carinatus* (Günther, 1858)
Keeled Rat Snake

Ptyas carinatus is almost as frequently encountered as *Maticora bivirgata* at Bukit Timah (13 records). There were a total of 21 records during the survey. A large species reaching 4 m, it feeds on frogs and terrestrial rodents.

30. *Ptyas korros* (Schlegel, 1837)
Indo-Chinese Rat Snake

There were only five records of this species, but it is not confined to the Nature Reserves. It is perhaps commoner in cultivated and rural areas.

31. *Rhadophis subminiatus* (Schlegel, 1837)
Red-necked Keelback

Tentatively a rediscovery, a single record of this handsome snake was obtained in 1994, at Mandai. Lim & Lee (1989) stated that *R. subminiatus* is "recorded mainly from the northern parts of Peninsular Malaysia, Thailand and south China". It is possible that this record was of an escapee from the Singapore Zoological Gardens.

32. *Sibynophis melanocephalus* (Gray, 1834)
Black-headed Collared Snake

This terrestrial species is considered uncommon as it is not often encountered - there were only six records from the survey, including an example caught in a pitfall trap. It is, however, not confined to the forest.

33. *Xenelaphis hexagonotus* (Cantor, 1847)
Malayan Brown Snake

This is a large but inoffensive snake, more commonly found in open country and cultivated areas, often near water. Lim & Lee (1989) reported a diet consisting of rodents, amphibians and fish. There are only two recent records from the Nature Reserves.

34. *Xenochrophis maculatus* (Edeling, 1865)
Spotted Keelback

This species was recently rediscovered in 1989 at Bukit Timah. A second pre-survey record was obtained at MacRitchie in 1991. During the survey period, there were 12 more records with 11 from Lower Peirce and 1 from MacRitchie. Unfortunately, except for the latter, all other records were of road-kills.

35. *Xenochrophis piscator* (Schneider, 1799)
Chequered Keelback

There were four records at Upper Seletar, but these were possibly of escapees (Lim & Lim, 1988; Lim & Lee, 1989).

36. *Xenochrophis trianguligerus* (Boie, 1827)
Triangle Keelback, Red-sided Water Snake
Plate 3b

This species was rediscovered in 1995 at Lower Peirce, but only a moult was found.

37. *Zaocys fuscus* (Günther, 1858)
White-bellied Rat Snake, Brown Rat Snake

A snake, possibly of this species, was observed beside a pool in 1997 at Nee Soon (S.H. Yeo, *pers. comm.*). If confirmed, the record constitutes a rediscovery of this highly endangered snake.

Family **Elapidae**

38. *Maticora bivirgata* (Boie, 1827)
Blue Malayan Coral Snake

This highly venomous species is the commonest snake at Bukit Timah (15 records) and is also frequently encountered at MacRitchie (nine records). In addition, it is one of the commonest terrestrial snakes in the Nature Reserves (26 records). One of our most beautiful snakes, *M. bivirgata* often lies across a track to soak in the sun. As a result, visitors to the Nature Reserves often chance upon it. Fortunately, it is not aggressive and makes its escape rather than standing its ground. The first author has

observed an example flattening itself against the ground and raising its bright red tail when cornered. Though not necessarily a forest dweller, *M. bivirgata* has not been recently recorded outside the Nature Reserves, and the authors consider it an uncommon species in Singapore.

39. *Maticora intestinalis* (Laurenti, 1768)
Banded Malayan Coral Snake

A close cousin of the above, this species is rather widespread in the Nature Reserves, but is commoner at MacRitchie, where 11 were recorded. Unlike *M. bivirgata*, most of the records were of road-kills. The species is also found in areas fringing the Nature Reserves.

40. *Naja sumatrana* Müller, 1887
Black Spitting Cobra

This very dangerous species is more common than most people think. It can be found in gardens, parks and scrubland, as well as the Nature Reserves (11 records). Hiding in the day, it emerges at night to hunt for small animals. This species has the ability to spit venom accurately at the eyes, and should not be approached, as it is highly irritable.

41. *Ophiophagus hannah* (Cantor, 1836)
King Cobra, Hamadryad

The largest venomous snake in the world, *O. hannah* was recorded only four times in the past decade - three at MacRitchie and one at Nee Soon. In the mid 1980s, the first author also recorded a juvenile at Pulau Tekong. The species can grow to about 6 m. It feeds on other snakes (ophiophagous), particularly rat snakes (Lim & Lee, 1989).

Family **Viperidae**

42. *Tropidolaemus wagleri* (Boie, 1827)
Wagler's Pit Viper

This beautiful snake is green when young, slowly developing black barrings and a bright yellow venter as it matures. It is usually seen on shrubs or low branches, and stays motionless to avoid detection. When disturbed it is sluggish and usually unaggressive. This snake has heat-sensing organs and presumably feeds on small mammals and birds. There were 12 records

from the survey - six at Bukit Timah, five at MacRitchie and one at Mandai. It is also recorded from mangroves, and the first author has a record from a rubber plantation on Pulau Tekong.

ORDER **SAURIA**
Family **Varanidae**

43. *Varanus nebulosus* (Gray, 1831)
Clouded Monitor

Lim & Lim (1992) listed *V. nebulosus* as a rare species, and prior to the survey, there was only a single record for Singapore. There were, however, 32 records from the survey period. This species had probably been mistaken for the more familiar *V. salvator* in the past. The status of the species is now considered to be fairly common. MacRitchie is the stronghold for *V. nebulosus* (23 records), where it is often seen clinging onto tree trunks.

44. *Varanus salvator salvator* (Laurenti, 1786)
Malayan Water Monitor, Asian Water Monitor, Common Water Monitor

This is the monitor commonly seen in mangroves, on offshore islands and even along canals in urban areas. Large specimens are common in and around Sungei Buloh Nature Park. As its name suggest, *V. salvator* swims readily, especially when threatened. Within the Nature Reserves, it is usually found on the fringes of the reservoirs.

Family **Scincidae**

45. *Dasia* cf. *grisea* (Gray, 1845)
Brown Tree Skink

This skink is a new record for Singapore and its presence was confirmed in 1996 at Nee Soon (S.H. Yeo, *pers. comm.*). The second author recorded an example in 1994 at MacRitchie. It has a brown dorsum with black transverse barrings with white below the eye. The juvenile is yellow-brown with thicker, more defined barrings and a series of spots on the head. The underparts are yellowish in colour.

46. *Dasia olivacea* Gray, 1839
Olive Tree Skink

There were a total of nine records of this endangered species, including four juveniles at Nee Soon. The other records came from Bukit Timah. The adult is olive brown dorsally with indistinct black transverse barrings, whereas the juvenile has a yellowish head and tail, and a blackish body with thin yellowish barrings. The underparts are light green. An example from Bukit Timah had no barring on the dorsum. There is a possibility that the records involve more than a single species of *Dasia*.

47. *Lipinia* cf. *vittigera* (Boulenger, 1894)
Yellow-striped Skink

There were four records of this newly discovered species at Bukit Timah. Another was seen after the survey period, at Upper Seletar, within the grounds of the Night Safari (T.M. Leong, *pers. comm.*). This striking skink is usually observed on tree trunks. A broad yellow band runs dorsally from the snout to the end of the tail. A broad black band is found on each side of the yellow band, but tapers off towards the tail.

48. *Lygosoma* sp.
Supple Skink A

Two specimens of a skink species were collected in 1989 and 1990 near a stream at Nee Soon, but their identity is still not determined.

49. *Mabuya multifasciata* (Kuhl, 1820)
Common Sun Skink, Sun Lizard

This handsome skink is very common in any wooded area, and is often seen sunning itself along trails and footpaths. There were 121 records from the survey, making it the second most numerous reptile, after *Cuora amboinensis*. Although highly approachable, it is extremely difficult to catch. The coloration varies from bronze to yellow-brown, and often the sides are a bright orange and the throat a deep yellow.

50. *Mabuya rugifera* (Stoliczka, 1870)
Striped Sun Skink

There were only five records of this endangered species during the survey (Bukit Timah and Nee Soon). All were found in clearings in the forest. The second author eventually recorded another in 1998 at Thomson Ridge, MacRitchie.

51. *Riopa bowringi* (Günther, 1864)
Garden Supple Skink

This tiny skink is more easily seen in urban areas, where it often crawls out of grass to sun itself. It is probably found all over Singapore. Within the Nature Reserves, only one record was obtained. However, the use of pitfall traps (with sealed bottoms) may perhaps produce more records.

Family **Agamidae**

52. *Aphaniotis fusca* (Peters, 1864)
Earless Agamid

The only known population of *A. fusca* in CCNR, prior to the survey period, was at the fringes of Upper Seletar Reservoir Park (Nee Soon), where two individuals were recorded. Two other populations have since been located during the survey, at MacRitchie North and Three-Stone Hill (Nee Soon), with four records at each location. At Bukit Timah, two were recorded during the pre-survey period and another four during the survey period.

53. *Bronchocela cristatella* (Kuhl, 1820)
Green Crested Lizard

This beautiful agamid used to be very common in urban and suburban areas. It is now more frequently encountered in parks and wooded areas. It is suspected that its populations have dwindled due to competition from *Calotes versicolor*. The species is, however, surviving well on the fringes of the Nature Reserves. Extensive culling of *C. versicolor* may allow this species to make a comeback in its lost niches.

54. *Calotes versicolor* (Daudin, 1802)*
Changeable Lizard

A feral species, *C. versicolor* was supposedly introduced in the 1980s, and has since spread to every urban, suburban and rural area. It has, however, not penetrated the Nature Reserves, except at the fringes.

55. *Draco melanopogon* Boulenger, 1887
Black-bearded Flying Dragon

Due to its arboreal habits, this species has probably been overlooked by

many. Confined to the Nature Reserves, it is uncommon (36 records) but rather widespread. Males have a red and black gular flag. To the untrained eye, it is similar to *D. volans*, but its colour is greener, and it is larger and proportionately more slender.

56. *Draco volans sumatrana* Schegel, 1844
Common Flying Dragon

This species can be found in any area with trees, and it may surprise many that it can often be seen in housing estates. It is equally at home in the Nature Reserves, where 23 were recorded. Unlike *D. melanopogon*, it has a yellow gular flag, tinged with blue.

Family **Gekkonidae**

57. *Cnemaspis kendalli* (Gray, 1845)
Kendall's Rock Gecko

Bukit Timah is the key sanctuary (50 records) for this forest species, although Nee Soon probably has a sizeable population as well (five records). There was one record each from MacRitchie, Mandai and Upper Seletar. Rajathurai (1996a) reported an example found in a culvert, at Pulau Tekong Besar, the only known record outside the Nature Reserves. This record needs verification, however, as *C. kendalli* can easily be confused with *Gekko monarchus*. *Cnemaspis kendalli* is usually seen on tree trunks and rocks, and often raises its tail over its back when alarmed. Strangely, regenerated tails are yellow.

58. *Cosymbotes craspedotus* (Mocquard, 1890)
Frilly Gecko
Plate 3c

Lim (1991c) recorded the recent discovery of this species at Nee Soon. A second example of this highly endangered species was subsequently found during the survey period at the same locality. The first record for Bukit Timah was by the second author in 1998, after the survey period when an example was seen on a tree along Tiup Tiup Path. It has bright yellow underparts and is mottled brown dorsally with a series of dark brown blotches down the length of the body. A fringe of loose skin is found on the sides of the head, body, tail and feet. This cryptic morphology allows it to blend into the surface of tree trunks or rocks.

59. *Cosymbotes platyurus* (Schneider, 1792)
Flat-tailed Gecko

This familiar species resembles *C. craspedotus*, but is not as cryptic. It also has a fringe of skin on the sides of the head, body, tail and feet, although this is much less pronounced. Furthermore, its undersides are also yellow and under dim light, its beige-brown coloration changes to reveal a similar series of dark brown blotches down the body. Within the Nature Reserves, it is usually found on buildings and concrete structures, especially where there is a light source.

60. *Cyrtodactylus* cf. *consobrinus* (Peters, 1871)
Banded Bent-toed Gecko, Giant Bent-toed Gecko, Peter's Bent-toed Gecko
Plate 3d

The opening of the man-made tunnels at Bukit Timah led to the discovery of *C. consobrinus* in 1993. Prior to this, it had apparently been observed at least once at Jungle Fall Valley, but could not be identified. To date, there are 23 records from Bukit Timah but none from elsewhere. This primary forest species grows to at least 30 cm, and is often found together with *Cnemaspis kendalli*, which it possibly preys on. The coloration varies from light to dark purplish-brown, with transverse light yellowish bands on the body, tail and limbs. There is an elaborate, but more or less distinctive, network of pale yellow on the head and neck.

61. *Cyrtodactylus quadrivirgatus* Taylor, 1962
Marbled Bent-toed Gecko, Marbled Forest Gecko

A total of eight records of *C. quadrivirgatus* were obtained during the pre-survey period and 20 from the survey period. Most records came from Nee Soon and Upper Seletar. There was only a single record from Bukit Timah, where an example was released after having "hitch-hiked" all the way from South Johor. It is most unusual that no natural populations of *C. quadrivirgatus* were located at Bukit Timah, as it seems to have the same niche as *Cnemaspis kendalli*.

62. *Gehyra mutilata* (Wiegmann, 1835)
Four-clawed Gecko

Another gecko associated with human dwellings, *G. mutilata* is perhaps more adaptable to the forest environment. Juveniles have pink or gold

spots on the body (Lim & Lim, 1992) and white spots on the face, which slowly fade with maturity. This species has only four-clawed digits, and a head that is more rounded and blunt than the other gecko species. The call is a series of low and monotonous squeaks. *Gehyra mutilata* is quite easily seen along the pipeline at Nee Soon.

63. *Gekko monarchus* Duméril & Bibron, 1836
Spotted House Gecko

This species is rarely seen in housing estates, but is usually found in houses and structures near wooded areas, including culverts and covered drains. Most survey records came from Bukit Timah and Nee Soon. Juveniles have a banded tail and a row of paired spots from head to tail - markings that become indistinct with age. The skin of the adult is covered with prominent, sharp tubercles. Eggs are laid in large clusters cemented together, and attached to hard surfaces. Like *Gehyra mutilata*, it has only four-clawed digits.

64. *Gekko smithi* Gray, 1842
Large Forest Gecko, Stentor's Gecko

Largest of our geckoes, *G. smithi* is more commonly heard than seen. Adults grow to over 35 cm and can give a nasty bite. They are most commonly found on dead or dying trees. This species has distinctive green eyes and an Y-shaped marking on the head. The dorsum and tail has transverse, dark brown bands. In addition, the bands on the body are bordered with large white spots. These beautiful markings are more pronounced in very young juveniles. Bukit Timah is the main refuge for this forest gecko (17 records), although it also occurs at Nee Soon (five records) and Lower Peirce (two records).

65. *Hemidactylus frenatus* Duméril & Bibron, 1836
Common House Gecko

Very familiar by sight and sound to all Singaporeans, *H. frenatus* (together with *Cosymbotes platyurus*) is presumably found in every housing block in Singapore. Within the Nature Reserves, it is usually found on buildings with light sources.

66. *Hemiphyllodactylus typus typus* Bleeker, 1860
Dwarf Gecko

This diminutive gecko was found on bushes in MacRitchie (five records).

A specimen was also collected at Upper Peirce East, from a resam patch that was being cleared. The only recent record outside the Nature Reserves was at the Mandai mangroves (Lim *et al.*, 1993b).

ORDER **CROCODILIA**
Family **Crocodylidae**

67. *Crocodylus porosus* Schneider, 1801
Estuarine Crocodile, Saltwater Crocodile

All recent records of this species within the Nature Reserves are probably of escapees. It has been seen at Upper Seletar Reservoir and MacRitchie Reservoir.

ORDER **TESTUDINATA**
Family **Emydidae**

68. *Cuora amboinensis* (Daudin, 1802)
Malayan Box Terrapin

Cuora amboinensis is the commonest reptile in the survey (133 records). It is primarily herbivorous and is found in large numbers in the reservoirs and adjoining streams. Though amphibious, juveniles are apparently entirely aquatic (Ernst & Barbour, 1989). Existing populations consist of both indigenous and feral animals, as Buddhist devotees often release the species on Vesak Day.

69. *Heosemys spinosa* (Gray, 1831)
Spiny Terrapin, Spiny Hill Terrapin

Our only true forest terrapin, this uncommon species (29 records) was recorded from all zones. This is the most terrestrial of our turtles. It is often encountered walking on the forest floor, sometimes not far from water. A juvenile with a serrated carapace was recorded at Bukit Timah, indicating a breeding population there. A few examples were caught in spring-door traps laid out for small mammals.

70. *Notochelys platynota* (Gray, 1834)
Malayan Flat-shelled Terrapin

This species is easily identified as it has six to seven vertebral scutes. There

were six records from the survey. It is found in shallow waters, where it feeds on aquatic plants (Ernst & Barbour, 1989).

71. *Siebenrockiella crassicollis* (Gray, 1831)
Black Marsh Terrapin, Black Pond Terrapin

This nocturnal species is abundant in the reservoirs and their inlets. It is largely carnivorous, feeding on snails, worms, shrimps and other invertebrates. This species is another favourite with Buddhist devotees on Vesak Day, and released feral animals probably form a substantial part of the population.

72. *Trachemys scripta elegans* (Wied, 1839)*
Red-eared Terrapin, Common Slider

This feral species is well established in reservoirs and lakes. It is especially numerous at the Botanic Gardens, where the first author observed one laying eggs. There were 87 records from the survey, but fortunately, the species has not established itself in forest streams. This amphibious terrapin is more at home in the water, but loves to sun itself on floating logs or at the water's edge.

Family **Trionychidae**

73. *Amyda cartilaginea* (Boddaert, 1770)
Asiatic Soft-shelled Turtle

A large species, *A. cartilaginea* was mostly recorded from the reservoirs and adjoining streams (eight records). Adults have carapaces of up to 70 cm in length. This species and *Pelodiscus sinensis* are often slaughtered to make turtle soup.

74. *Dogania subplana* (Geoffroy, 1809)
Forest Soft-shelled Turtle, Malayan Soft-shelled Turtle
Plate 3e

Recently rediscovered in 1989 at Nee Soon, *D. subplana* is restricted to clean forest streams. A second record was obtained in 1991 at Rifle Range Forest (MacRitchie). This attractive turtle has a diagnostic vertebral stripe and two to three pairs of ocelli on the carapace. Juveniles have a reddish patch at the sides of the head, which disappear with maturity.

75. *Pelodiscus sinensis* (Wiegmann, 1835)*
Chinese Soft-shelled Turtle

There were 10 records of this feral species that has established itself in reservoirs, lakes and canals.

Amphibians

Nomenclature for amphibians generally follows Lim & Lim (1992) and Berry (1975). For most species, the convention and criteria used in describing the abundance of amphibians are as follows (numbers indicate known population size in Singapore):

- **Endangered** : Occurring in very low numbers (< 30)
- **Rare** : Occurring in low numbers (30–59)
- **Uncommon** : Occurring in moderate numbers (60–119)
- **Fairly Common** : Occurring in high numbers (120–179)
- **Common** : Occurring in very high numbers (> 179)

During the pre-survey period, 20 indigenous species were recorded. The survey Period produced 24 species making a total of 25 indigenous species recorded from 1987 to July 1997 of which 18 are forest species (72%) and seven others not restricted to forest. The Nature Reserves are the only refuge for 16 species (64%).

Bukit Timah and Nee Soon are strongholds for threatened amphibians (Figure 9). Of the 25 indigenous species, 14 (56%) are considered threatened - seven endangered, four rare and three uncommon. These include the four localized species, *Pelophryne brevipes*, *Microhyla borneensis*, *Theloderma horridum* and *Rhacophorus bimaculatus*. The distribution of endangered and rare amphibians is mapped out in Figure 10.

ORDER **GYMNOPHIONA**
Family **Ichthyophiidae**

1. *Ichthyophis* cf. *paucisulcus* (Taylor, 1960)
Yellow-banded Caecilian

The only record for CCNR was in 1989 (Lim, 1990a) at Nee Soon. There are only two other recent records, both from Bukit Timah (Ng *et al.*, 1988; Ng, 1989). This species is perhaps overlooked, as it lives under soil in the vicinity of streams.

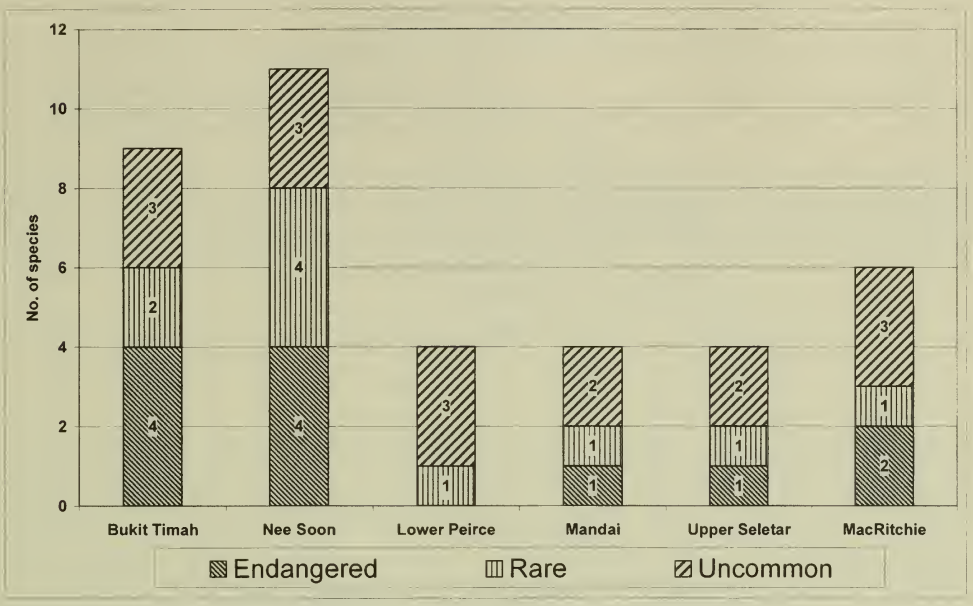


Figure 9. Number of threatened amphibian species in the Nature Reserves.

ORDER **ANURA**
Family **Pelobatidae**

2. *Megophrys nasuta* (Schlegel, 1858)
   Malayan Horned Frog, Malayan Horned Toad

There were 16 records of this cryptic frog from the pre-survey period and 36 from the survey period. Although Lim (1994) considered this species to be uncommon, we are listing it as rare, based on the relatively low number of records. Furthermore, the main populations are confined to Bukit Timah (40 records) and Nee Soon (10), with only a single record each from Upper Seletar and Mandai.

3. *Leptobrachium nigrops* Berry & Hendrickson, 1963
   Black-eyed Litter Frog

This species is common in the Nature Reserves usually near streams or larger water bodies, it is more often heard than seen,. There were 158 records from the survey period. It has never been recorded far from the Nature Reserves.

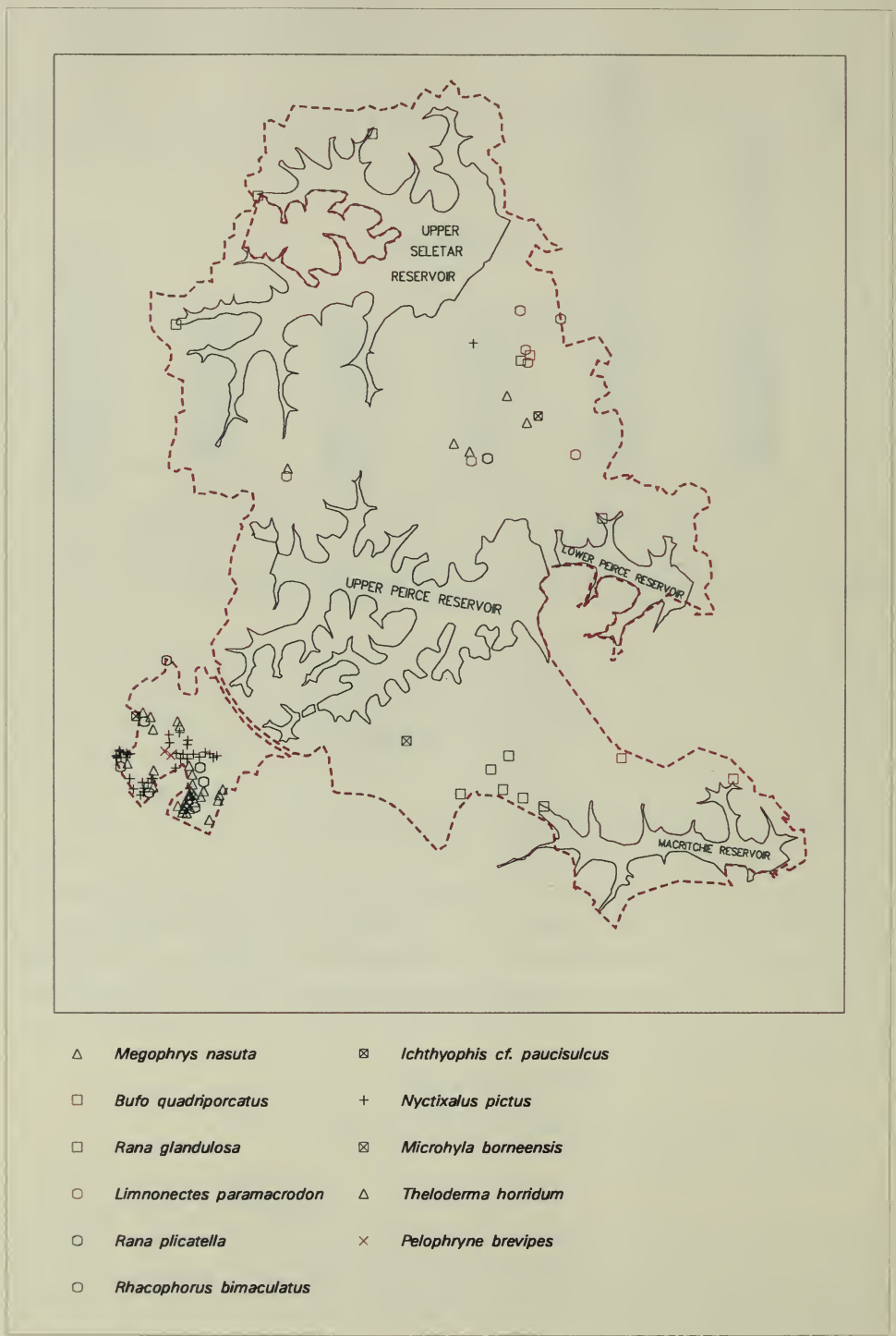


Figure 10. Distribution of endangered and rare amphibians.

Family **Bufonidae**

4. *Bufo melanostictus* Schneider, 1799
   Asian Toad, Asiatic Toad

This ubiquitous species is found all over Singapore. It has even managed to penetrate primary forest in the Nature Reserves, and is especially common at Bukit Timah (60 records).

5. *Bufo quadriporcatus* Boulenger, 1887
   Four-ridged Toad

A recent discovery from MacRitchie (Lim, 1989a), *B. quadriporcatus* is found near swampy areas. A total of eight were recorded in the pre-survey period, four each at MacRitchie and Nee Soon. During the survey, there were three more records - two at MacRitchie and one at Nee Soon. Although Lim (1994) stated that this species is "commonly heard" in Nee Soon, the authors are of the opinion that it is endangered.

6. *Pelophryne brevipes* (Peters, 1867)
   Saint Andrew's Cross Toadlet

A primary forest species, *P. brevipes*, was rediscovered in 1989 at Bukit Timah, where only two were recorded (Lim, 1990b). There were only two other records from the past, making this a highly endangered amphibian.

Family **Ranidae**

7. *Limnonectes blythii* (Boulenger, 1920)
   Malayan Giant Frog, Blyth's Frog

Our largest indigenous frog, *L. blythii* can grow to over 20 cm. It is widespread, but confined to the Nature Reserves. Its habits are very similar to *Limnonectes malesiana*.

8. *Limnonectes malesiana* Kiew, 1984
   Malesian Frog

Though uncommon, *L. malesiana* is widespread and occurs in all zones. This large species is often encountered sitting in shallow streams or by the edge of reservoirs within the Nature Reserves.

9. *Limnonectes paramacrodon* (Inger, 1966)
Masked Swamp Frog
Plate 4a

This rare species was officially recorded for Singapore in 1988 at Nee Soon, although a specimen was collected in 1974 at the same locality (Lim, 1989b). There were 26 records in the pre-survey period, all from Nee Soon. In the survey period, nine records were obtained - eight at Nee Soon and one from a new locality at Chestnut Track Forest (Mandai). *Limnonectes paramacrodon* is dependent on swamp forest habitat.

10. *Occidozyga laevis* (Günther, 1859)
Smooth Puddle Frog, Yellow-bellied Puddle Frog

A tiny frog, *O. laevis* is found in puddles and waterlogged areas. Distinct morphological variation in different areas was observed, as all frogs from Upper Seletar North were plain brown with a patch of orange on the snout.

11. *Rana baramica* Boettger, 1901
Masked Rough-sided Frog

This species is usually found in marshy areas, but the first author has recorded one on leaf litter far from water at Bukit Timah. It is widely distributed in the Nature Reserves, but has not been encountered outside the Nature Reserves.

12. *Rana cancrivora* Gravenhorst, 1829
Crab-eating Frog, Mangrove Frog

This frog can tolerate brackish water, and is more commonly found near the coast, in mangroves, prawn ponds and cultivated land. The young frogs sold as fish feed in aquarium shops are of this species.

13. *Rana chalconota* (Schlegel, 1837)
Copper-cheeked Frog, White-lipped Frog

This is without doubt the commonest frog in the Nature Reserves - a total of 526 records were obtained in the survey. It is easily detected through its call and is often found on low vegetation.

14. *Rana erythraea* (Schlegel, 1837)
Common Greenback, Green Paddy Frog

More aquatic than most other frogs in Singapore, *R. erythraea* is usually found near open water bodies, never in true forest. It is widespread in the Nature Reserves.

15. *Rana glandulosa* Boulenger, 1882
Rough-sided Frog
Plate 4b

This species was first recorded for Singapore in 1993 from MacRitchie North. Four examples were recorded then, and the area was subsequently found to have the largest population (42 records). Ten more individuals were found in three other zones, making a total of 52 records for the survey. It is not surprising that previous researchers have missed the species - most of our records were based on its call, which was learned only during the survey. Although rather widespread, *R. glandulosa* is currently recorded only from CCNR and is considered rare.

16. *Rana limnocharis* Boie, in Wiegmann, 1835
Field Frog, Grass Frog

This very common frog is found in most habitats in Singapore. In urban areas, it can be encountered in fields, especially after rain. *Rana limnocharis* is widespread in the Nature Reserves where it is usually recorded in disturbed areas like reservoir edges and ditches.

17. *Rana plicatella* Stoliczka, 1873
Rhinoceros Frog

The main population of *R. plicatella* occurs at Bukit Timah, where its call, a slowly rising, quivering warble, is often heard. The species is, however, still considered rare, as there were only three records outside Bukit Timah (at Nee Soon). There were a total of seven records from the pre-survey period and 50 records from the survey period. *Rana plicatella* is found in shallow streams and often hides under nearby leaf litter. When disturbed, it makes quick short hops for cover, and has even been observed to hop sideways.

Family **Rhacophoridae**

18. *Rhacophorus bimaculatus* (Peters, 1867)
Blue-legged Tree Frog

Rhacophorus bimaculatus was first discovered over 30 years ago from the Nee Soon (Lim & Yang, 1991), but was not recorded again until 1994. The first author chanced upon the single example at Nee Soon, at the edge of a forest stream (Lim, 1994a). It was not as brightly coloured as examples from Malaysia.

19. *Nyctixalus pictus* (Peters, 1871)
Spotted Tree Frog, Painted Tree Frog

A healthy population of *N. pictus* holds out in Bukit Timah - a total of 67 records were obtained during the survey period. We only learned to recognize its calls during the survey at Bukit Timah, and it is suspected that the species will be found to be more widespread at CCNR, where 6 tadpoles were recorded in 1996 at Nee Soon (T.M. Leong, *pers. comm.*).

20. *Polypedates leucomystax* (Boie, in Gravenhorst, 1829)
Common Tree Frog, Four-lined Tree Frog

Polypedates leucomystax is a common species, even in gardens and parks around Singapore. It can sometimes be found clinging onto walls of houses. It is most commonly found on low vegetation, and is easily located by its call. At night, *P. leucomystax* is brown in color, usually with stripes or spots on the back, but in the daytime, it sometimes turns pale beige.

21. *Theloderma horridum* (Boulenger, 1903)
Thorny Tree Frog
Plate 4c

Leong *et al.* (1996) recorded the discovery of this very cryptic rhacophorid. Five other records were obtained from Taban Valley at Bukit Timah. This species was found clinging onto tree trunks, 1–2 m from the forest floor. It is superbly camouflaged against lichen-covered bark. In the day, the frog probably hides in the canopy, but descends down the trunk at night to look for food.

Family **Microhylidae**

22. *Kaloula pulchra* Gray, 1831*
Banded Bullfrog, Painted Bullfrog

In urban areas, the bellowing call of this feral species is characteristic after a downpour. It is beginning to penetrate the Nature Reserves - a total of 13 were recorded during the survey. This frog hides in crevices or burrows into the sides of ditches during the day. It has also been found hiding 1–2 m above ground, usually in the fork of a tree.

23. *Kalophrynus pleurostigma* Tschudi, 1838
Black-spotted Sticky Frog

Previously known only from Bukit Timah (Lim & Yang, 1991; Lim & Lim, 1992), *K. pleurostigma* was first recorded from CCNR in 1993, at MacRitchie North, where one was found. By the end of the survey, a total of four had been recorded (two at MacRitchie, one at Nee Soon, and one at Lower Peirce). Although these are the only records from CCNR, the population at Bukit Timah was found to be large (70 records). The status of this primary forest species is hence updated to uncommon. This leaf-litter species is not dependent on streams and is usually found on the forest floor. It probably breeds in puddles and any water-filled hole or receptacle, including the ground cups of pitcher plants (Lim & Lim, 1992). Inger & Stuebing (1997) reported that *K. pleurostigma* (in Borneo) feeds mainly on ants and termites.

24. *Microhyla borneensis* Parker, 1926
Bornean Narrow-mouthed Frog, Bornean Chorus Frog
Plate 4d

Leong & Chou (1997) reported the first record of this primary forest frog in Singapore. It is known only from Rifle Range Forest (MacRitchie) where five were recorded in 1996 (one specimen collected and four others heard). Tadpoles were also found in the same location. More intensive work on leaf-litter fauna, will probably produce more records of this species, and perhaps lead to the discovery of other microhylids.

25. *Microhyla butleri* Boulenger, 1900
Painted Narrow-mouthed Frog, Painted Chorus Frog

Seldom seen, but actually very common, this species is usually detected

through its call. Males gather in large calling groups near small pools of water or ditches.

26. *Microhyla heymonsi* Vogt, 1911
Dark-sided Narrow-mouthed Frog, Dark-sided Chorus Frog

This species is similar in behaviour to *M. butleri*, and can often be found together with it. Likewise, it is very common all around Singapore.

Discussion

The Nature Reserves are the only protected refuges for the incredible diversity of flora and fauna that survives in rain forest. Yet, in this century, very few studies of our rain forest fauna have been carried out. The few projects that have been conducted at BTNR were usually short-term, sporadic and narrow in scope. In recent years, there has been a notable increase in observer effort to document sightings of fauna, especially mammals, reptiles and amphibians. However, no long-term research projects had been initiated until this survey. It is therefore not surprising that so many species have been "missing" in recent decades.

Comparing data from the pre-survey period to that from the survey period indicates that casual observation alone is insufficient to have a good picture of the diversity, abundance and distribution of mammal, reptile and amphibian species. One reason is that many species are not easily observed, let alone identified, in the field (e.g., bats and murids). For instance, because proper studies on bats had not been conducted for about 70 years, 20 out of the 25 species in Yang *et al.* (1990) were listed as indeterminate. Yet, Pottie (1996) reported the rediscoveries of nine microchiropterans, as well as the addition of two new species to Singapore's checklist! In addition, three megachiropterans were also rediscovered in the same project.

Another reason is that most species are also nocturnal, making detection even more difficult, and species with small, localized populations are easily overlooked. Only sufficient time in the field, using proper survey techniques, would help us better understand the present situation regarding our mammals, reptiles and amphibians.

The survey has certainly been successful in updating our knowledge on the mammals, reptiles and amphibians. Data collected on forest species, especially mammals, are the most thorough in a few decades. Coupled with data from the pre-survey period, the survey has given us a good baseline assessment of the current diversity, abundance and distribution of

species in the Nature Reserves. Of the 141 indigenous species recorded, 74 are forest species (52%) that are highly dependent on forest habitats for their survival. About 85% of these species are locally threatened with extinction and their future survival will depend greatly on the sound management and protection of Nature Reserves. Their abundance and distribution are good indicators of the condition of our forests and indeed the health of our Nature Reserves.

Diversity and distribution

The Nature Reserves still have a very high diversity of indigenous mammals, reptiles and amphibians (141 species), representing about 86% of all species that are known to still exist in Singapore. Of the six zones, Bukit Timah, Nee Soon and MacRitchie are the best known and have received good coverage by researchers and casual observers throughout the past decade. They are the most diverse in terms of species occurring, and support the most number of threatened species. This is not surprising as these zones hold the bulk of primary habitats left in the Nature Reserves.

1. Bukit Timah

Bukit Timah is probably the best-known nature site in Singapore and has received fairly good coverage by researchers and casual observers, both in the past and in recent times. Research has, however, been largely confined to specific studies such as that on *Macaca fascicularis* (Corlett & Lucas, 1995).

About half of Bukit Timah supports original Coastal Hill Dipterocarp Forest, the only forest of this kind in Singapore. This habitat, together with the adjacent secondary habitats, is most important as a major refuge for a large diversity of indigenous species including a high number that are threatened. With 50 threatened species recorded, Bukit Timah is the most vital zone for mammal, reptile and amphibian species. It is home to ten localized species and the main populations of seven other species. This is astounding as Bukit Timah is one of the smallest zones.

2. Nee Soon Zone

Nee Soon includes the only primary freshwater swamp forest left in Singapore, as well as good tracts of primary lowland dipterocarp forest at Three-Stone Hill and Nee Soon East. It is the second most important area for indigenous mammals, reptiles and amphibians (89 species), as well as

threatened species (46 species). Nee Soon also has the second highest number of localized species with six species that are currently not known to occur outside this zone. In addition, Nee Soon holds the main populations for three species that were only discovered within the last decade. The whole zone is therefore vital as a core area for the northern half of CCNR.

3. MacRitchie Zone

The most substantial stands of primary lowland dipterocarp forest (over 250 ha) are to be found within this zone, at MacRitchie North and Thomson Ridge. There is also a 160-ha freshwater swamp forest, which is distinct from that at Nee Soon. Together, they form the core area for the southern half of CCNR. However, the other sectors in MacRitchie are also important, as they consist mainly of mature secondary forest. Given time, these areas will be comparable to the primary vegetation.

MacRitchie has the third highest diversity of indigenous species (88 species) and threatened species (40 species). With two discoveries and three localized species, MacRitchie is unquestionably a key area for mammals, reptiles and amphibians.

4. Lower Peirce Zone

The diversity of indigenous species at Lower Peirce is surprisingly impressive (77 species), when we consider that it is a relatively small area, consisting mainly of secondary forest. One obvious reason for this is that Lower Peirce is basically continuous with Nee Soon. For example, *Presbytis femoralis* has "colonized" Lower Peirce from Nee Soon with perhaps two troops in the zone. For many other threatened species at Nee Soon, Lower Peirce represents a natural extension to their range, and offers opportunities for expansion of their populations.

The large number of road-kill records at Old Upper Thomson Road is unfortunate but interesting – it indicates that animals, especially snakes, are regularly crossing to and from the adjacent unprotected woodland.

5. Upper Seletar Zone

Prior to the survey, there were very few mammal, reptile and amphibian records from Upper Seletar. Furthermore, most of the pre-survey records came from the Singapore Zoological Gardens and its vicinity.

Upper Seletar is highly fragmented, and except for a few patches, the forest is mainly secondary in nature. Even so, its mammal and amphibian diversities are comparable to MacRitchie. This is largely due to the fact

that the zone also contains substantial areas of abandoned agricultural land where a good number of non-forest species were recorded. Still, Upper Seletar has a good number of threatened species, including four localized species.

6. Mandai Zone

As Mandai is rather inaccessible, records for this zone were practically non-existent prior to the survey (one indigenous species). During the survey, even though fieldwork was confined to a few trails, Mandai produced the greatest increase in diversity (52 indigenous species). In fact, Mandai has the highest mammal diversity (24 species) in CCNR. Reptile diversity was, however, very low – this was probably due to the lack of motorable roads and hence road-kill records. As much of the zone is still unexplored, many more species will definitely be recorded with continued surveys and casual visits.

For survey purposes, Mandai was designated as a separate zone, but in actuality, it is totally continuous with Nee Soon. Together with Lower Peirce, they comprise the largest contiguous rain forest in Singapore and one of the core areas for mammal, reptile and amphibian conservation. The importance of this cannot be over-emphasized – the combined species diversity accounts for over 80% of CCNR's total checklist.

Abundance

A remarkable 80 species (57%) are considered threatened. These include four subspecies unique to Singapore, and 24 localized species. In addition, about 35 species (25%) had only five or less records within the past decade for the whole of Singapore! This highlights the urgent need to increase conservation efforts to turn the tide. Measures to set aside core areas for the sole purpose of conservation and enhancing existing populations should be seriously looked into.

A few species are, however, deemed to be overly abundant within the Nature Reserves. These include *Tupaia glis*, *Cynopterus brachyotis*, *Macaca fascicularis*, *Sundasciurus tenuis* and *Rattus annandalei*. In Peninsular Malaysia, densities for these species within the forest are generally much lower. The exceptionally successful trappings of *T. glis*, and *R. annandalei* indicate a dominance of these species on the forest floor. The pressing question is whether the populations of these species are detrimental to rarer species like *Presbytis femoralis*, *Rhinosciurus laticaudatus*, *Maxomys surifer* and *M. rajah*.

Conclusions

Mammal, reptile and amphibian diversity in the Nature Reserves is still very high in relation to other nature areas in Singapore. The key areas for conservation are Bukit Timah, Nee Soon and MacRitchie, based on their high species diversity and the significantly greater number of threatened species. They should be set aside as core zones, with the incorporation of Mandai and Lower Peirce, which are contiguous with Nee Soon. This extended area has a higher carrying capacity than the key areas alone, and will allow mammal, reptile and amphibian populations within to thrive and flourish. Furthermore, Lower Peirce is especially important for snakes, and Mandai though insufficiently surveyed, has already shown its importance for mammal conservation.

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Appendix 1. Records of Mammals, Reptiles and Amphibians (1987–1998).

Species	BT	NS	LP	MD	US	MR	Total
Mammals							
?Pipistrellus sp.	5			3	2	19	**29**
Arctogalidia trivirgata	2	2					**4**
Callosciurus notatus	76	74	32	33	78	141	**434**
Cervus unicolor					3		**3**
Cheiromeles torquatus				5			**5**
Crocidura cf. *fuliginosa*	21	5		5			**31**
Cynocephalus variegatus	49	12	14	2	8	32	**117**
Cynopterus brachyotis	75	54	137	109	209	96	**680**
Emballonura monticola	6						**6**
Eonycteris spelaea			1	1	2	3	**7**
Hylopetes spadiceus	25						**25**
Iomys horsfieldii		2					**2**
Macaca fascicularis	335	272	81	55	111	604	**1458**
Manis javanica	1	2	1	2	2	8	**16**
Maxomys rajah		19	1	1			**21**
Maxomys sp.	1						**1**
Muntiacus muntjak				1			**1**
Myotis adversus			20	7	40	89	**156**
Myotis muricola	6	38		5	33	100	**182**
Nycteris tragata						2	**2**
Nycticebus coucang	1					1	**2**
Paguma larvata						1	**1**
Paradoxurus hermaphroditus			1	1	3		**5**
Penthetor lucasi	123						**123**
Presbytis femoralis		245	12				**257**
Pteropus vampyrus	5	7		3	6	162	**183**
Rattus annandalei	107	52	55	22	20	66	**322**
Rattus exulans					1		**1**
Rattus rattus	2				2		**4**
Rattus tiomanicus	10		1	2	1	5	**19**
Ratufa affinis	1	22					**23**
Rhinolophus lepidus	490	21	1	11	2	30	**555**

Species	BT	NS	LP	MD	US	MR	Total
Mammals							
Rhinolophus luctus				1		3	**4**
Rhinolophus trifoliatus		10		4		4	**18**
Rhinosciurus laticaudatus	1						**1**
Scotophilus kuhlii	50	57	23	61	77	109	**377**
Suncus murinus					3		**3**
Sundasciurus tenuis	111	135	79	42	188	228	**783**
Taphozous saccolaimus	15	59	8	55	49	71	**257**
Tragulus javanicus	2	7				3	**12**
Tupaia glis	323	98	32	90	63	117	**723**
Tylonycteris pachypus	1						**1**
Tylonycteris robustula	9	4	4	3		14	**34**
Viverra tangalunga					1		**1**
Reptiles							
Ahaetulla fasciolata	1						**1**
Ahaetulla prasina	8	2	3		14	6	**33**
Amyda cartilaginea		3	1		1	3	**8**
Aphaniotis fusca	6	6				4	**16**
Boiga cynodon	2		2		1	3	**8**
Boiga dendrophila	2	1	5	1		4	**13**
Boiga jaspidea			1		1		**2**
Bronchocela cristatella	5	1	3		8	4	**21**
Calamaria lumbricoidea	3		4		2	1	**10**
Calamaria schlegeli	8	3	11		1	3	**26**
Chrysopelea paradisi	4	2	7		2	7	**22**
Chrysopelea pelias	1	2	8			1	**12**
Cnemaspis kendalli	50	5		1	1	1	**58**
Cosymbotes craspedotus	1	2					**3**
Cosymbotes platyurus	30	1	1		11		**43**
Crocodylus porosus					3		**3**
Cuora amboinensis		25	5		32	71	**133**
Cyrtodactylus cf. *consobrinus*	23						**23**
Cyrtodactylus quadrivirgatus	1	15	2	2	6	3	**29**
Dasia cf. *grisea*		1				1	**2**
Dasia olivacea	4	5					**9**

Species	BT	NS	LP	MD	US	MR	Total
Reptiles							
Dendrelaphis caudolineatus	4	1	7		2	1	**15**
Dendrelaphis formosus	4	1	18		3	8	**34**
Dendrelaphis pictus	1		4		2	5	**12**
Dogania subplana		1				1	**2**
Draco melanopogon	11	1	9	1	2	12	**36**
Draco volans	2	5	1		5	10	**23**
Dryocalamus subannulatus	1	1	1				**3**
Dryophiops rubescens			1				**1**
Elaphe flavolineata	1	1	1			1	**4**
Gehyra mutilata	1	9			2	1	**13**
Gekko monarchus	25	12	6		2	7	**52**
Gekko smithi	17	5	2				**24**
Gonyosoma oxycephala	1	1				2	**4**
Hemidactylus frenatus	2		12	3	1	14	**32**
Hemiphyllodactylus typus		1				5	**6**
Heosemys spinosa	6	5	1	3	3	11	**29**
Homalopsis buccata		24	5	2	10		**41**
Liopeltis baliodeirus	1		4	1		5	**11**
Lipinia cf. *vittigera*	4						**4**
Lygosoma sp.		2					**2**
Mabuya multifasciata	33	8	18	21	8	33	**121**
Mabuya rugifera	3	2				1	**6**
Macropisthodon rhodomelas	4		2		1	3	**10**
Maticora bivirgata	15	1	1			9	**26**
Maticora intestinalis	4	1	6	1		11	**23**
Naja sumatrana	4		2	2		3	**11**
Notochelys platynota		1	1		1	3	**6**
Oligodon octolineatus	2	1	7	1	4	6	**21**
Oligodon signatus	1	1				2	**4**
Ophiophagus hannah		1				3	**4**
Ophites aulicus	1		1		1	7	**10**
Ophites subcinctus			1				**1**
Psammodynastes pictus		1					**1**
Pseudorhabdion longiceps	1	1	2		1	6	**11**
Ptyas carinatus	13	1			2	5	**21**

Species	BT	NS	LP	MD	US	MR	Total
Reptiles							
Ptyas korros	1				1	3	**5**
Python reticulatus	3	5	6	1	3	2	**20**
Ramphotyphlops braminus			1				**1**
Rhadophis subminiatus					1		**1**
Riopa bowringi	1						**1**
Sibynophis melanocephalus	2		1			3	**6**
Siebenrockiella crassicollis		4	6		21	43	**74**
Tropidolaemus wagleri	6			1		5	**12**
Varanus nebulosus	2	7	4		1	23	**37**
Varanus salvator	1		1		17	15	**34**
Xenelaphis hexagonotus	1				1		**2**
Xenochrophis maculatus	1		11			2	**14**
Xenochrophis piscator					4		**4**
Xenochrophis trianguligerus			1				**1**
Xenopeltis unicolor		1	3			5	**9**
Zaocys fuscus		1					**1**
Amphibians							
Bufo melanostictus	60	24	7	3	39	33	**166**
Bufo quadriporcatus		5				6	**11**
Ichthyophis cf. *paucisulcus*	1	1					**2**
Kalophrynus pleurostigma	70	1	1			2	**74**
Leptobrachium nigrops	21	79	45	26	5	25	**201**
Limnonectes blythii	36	17	9	2	13	77	**154**
Limnonectes malesiana	20	15	5	4	11	20	**75**
Limnonectes paramacrodon		34		1			**35**
Megophrys nasuta	40	10		1	1		**52**
Microhyla borneensis						5	**5**
Microhyla butleri		55		1	13		**69**
Microhyla heymonsi	18	20	8	1	80	27	**154**
Nyctixalus pictus	67	6					**73**
Occidozyga laevis	2	81		4	13	20	**120**
Pelophryne brevipes	2						**2**
Polypedates leucomystax	42	80	26	17	79	34	**278**
Rana baramica	3	19	18	5	17	34	**96**

Species	BT	NS	LP	MD	US	MR	Total
Amphibians							
Rana cancrivora	6		2		1		**9**
Rana chalconota	79	135	79	30	119	84	**526**
Rana erythraea	4	28	2	12	89	59	**194**
Rana glandulosa		1	3		7	42	**53**
Rana limnocharis	13	54	29	8	101	52	**257**
Rana plicatella	54	3					**57**
Rhacophorus bimaculatus		1					**1**
Theloderma horridum	5						**5**

Appendix 2. Checklist of Mammals, Reptiles and Amphibians of the Nature Reserves.

Key to Symbols

Conservation Status (CS)	Species Status (SS)	Sighting Record (SR)
En – Endangered	R - Resident	D - Discovery
Ra – Rare	FR - Feral (Reintroduced)	ReD - Recent Discovery
Un – Uncommon	FE - Feral (Exotic)	R - Rediscovery
Fc – Fairly Common	V - Visitor	ReR - Recent Rediscovery
Co – Common	FS - Forest Specialist	
In – Indeterminate	ES - Endemic Subspecies	
	LS - Localized Species	

A. Mammals

No.	Species	Common Name	CS	SS	SR
1.	*Arctogalidia trivirgata*	Small-toothed Palm Civet	En	R	R
2.	*Callosciurus notatus*	Plantain Squirrel	Co	R, ES	
3.	*Canis familiaris*	Feral Dog	Co	FE	
4.	*Cervus unicolor*	Sambar		FR, FS, LS	
5.	*Cheiromeles torquatus*	Naked Bat	En	R, LS	
6.	*Crocidura* cf. *fuliginosa*	South-east Asian White-toothed Shrew		En	R
7.	*Cynocephalus variegatus*	Malayan Colugo	Fc	R, FS	
8.	*Cynopterus brachyotis*	Lesser Dog-faced Fruit Bat	Co	R	
9.	*Emballonura monticola*	Lesser Sheath-tailed Bat	En	R, FS,LS	R
10.	*Eonycteris spelaea*	Cave Nectar Bat	Un	R	ReR
11.	*Hylopetes spadiceus*	Red-cheeked Flying Squirrel	En	R, FS, LS	D
12.	*Iomys horsfieldii*	Horsfield's Flying Squirrel	En	R, FS, LS	R
13.	*Macaca fascicularis*	Long-tailed Macaque	Co	R	
14.	*Manis javanica*	Sunda Pangolin	En	R	
15.	*Maxomys rajah*	Brown Spiny Rat	En	R, FS	D
16.	*Maxomys surifer*	Red Spiny Rat	In	R, FS, ES, LS	
17.	*Muntiacus muntjak*	Common Barking Deer		FR, FS, LS	
18.	*Myotis adversus*	Grey Large-footed Myotis	Co	R	ReR
19.	*Myotis muricola*	Whiskered Myotis	Co	R	
20.	*Nycteris tragata*	Hollow-faced Bat	En	R, FS, LS	D
21.	*Nycticebus coucang*	Slow Loris	En	R, FS	
22.	*Paguma larvata*	Masked Palm Civet	En	R, FS	R
23.	*Paradoxurus hermaphroditus*	Common Palm Civet	Un	R	
24.	*Penthetor lucasi*	Dusky Fruit Bat	En	R, FS, LS	R
25.	?*Pipistrellus* sp.	Pipistrelle A	Un	R	?R
26.	*Presbytis femoralis*	Banded Leaf Monkey	En	R, FS	
27.	*Pteropus vampyrus*	Large Flying Fox	Un	V	
28.	*Rattus annandalei*	Annandale's Rat	Co	R	
29.	*Rattus exulans*	Polynesian Rat	Co	R	
30.	*Rattus rattus*	House Rat	Co	R	
31.	*Rattus tiomanicus*	Malaysian Wood Rat	Un	R	
32.	*Ratufa affinis*	Cream-coloured Giant Squirrel	En	R, FS, ES	

A. Mammals

No.	Species	Common Name	CS	SS	SR
33.	*Rhinolophus lepidus*	Blyth's Horseshoe Bat	Fc	R, FS	D
34.	*Rhinolophus luctus*	Great Woolly Horseshoe Bat	En	R, FS	R
35.	*Rhinolophus trifoliatus*	Trefoil Horseshoe Bat	En	R, FS	R
36.	*Rhinosciurus laticaudatus*	Shrew-faced Ground Squirrel	En	R, FS, ES, LS	ReR
37.	*Scotophilus kuhlii*	Lesser Asiatic Yellow House Bat	Co	R	
38.	*Suncus murinus*	House Shrew	Co	R	
39.	*Sundasciurus tenuis*	Slender Squirrel	Co	R, FS	
40.	*Taphozous saccolaimus*	Pouched Tomb Bat	Co	R	ReR
41.	*Tragulus javanicus*	Lesser Mousedeer	En	R, FS, ES	
42.	*Tupaia glis*	Common Treeshrew	Co	R	
43.	*Tylonycteris pachypus*	Lesser Bamboo Bat	En	R, LS	R
44.	*Tylonycteris robustula*	Greater Bamboo Bat	Fc	R	
45.	*Viverra tangalunga*	Malay Civet	In	FS, R	

B. Reptiles

No.	Species	Common Name	CS	SS	SR
1.	*Ahaetulla fasciolata*	Speckle-headed Whip Snake	En	R, FS, LS	
2.	*Ahaetulla prasina*	Oriental Whip Snake	Co	R	
3.	*Amyda cartilaginea*	Malayan Soft-shelled Turtle	En	R	
4.	*Aphaniotis fusca*	Earless Agamid	Ra	R, FS	
5.	*Boiga cynodon*	Dog-toothed Cat Snake	En	R, FS	
6.	*Boiga dendrophila*	Yellow-ringed Cat Snake	Ra	R, FS	
7.	*Boiga jaspidea*	Jasper's Cat Snake	En	R, FS	
8.	*Bronchocela cristatella*	Green Crested Lizard	Fc	R	
9.	*Calamaria lumbricoidea*	Variable Reed Snake	Ra	R, FS	
10.	*Calamaria schlegeli*	Pink-headed Reed Snake	Un	R, FS	
11.	*Calotes versicolor*	Changeable Lizard		FE	
12.	*Chrysopelea paradisi*	Paradise Tree Snake	Co	R	
13.	*Chrysopelea pelias*	Twin-barred Tree Snake	Ra	R, FS	
14.	*Cnemaspis kendalli*	Kendall's Rock Gecko	Un	R, FS	
15.	*Cosymbotes craspedotus*	Frilly Gecko	En	R, FS	ReD
16.	*Cosymbotes platyurus*	Flat-tailed Gecko	Co	R	
17.	*Crocodylus porosus*	Estuarine Crocodile		FR	
18.	*Cuora amboinensis*	Malayan Box Terrapin	Co	R	
19.	*Cyrtodactylus* cf. *consobrinus*	Banded Bent-toed Gecko	En	R, FS, LS	ReD
20.	*Cyrtodactylus quadrivirgatus*	Marbled Bent-toed Gecko	Un	R, FS	
21.	*Dasia* cf. *grisea*	Brown Tree Skink	En	R, FS	D
22.	*Dasia olivacea*	Olive Tree Skink	En	R, FS	
23.	*Dendrelaphis caudolineatus*	Striped Bronzeback	Fc	R	
24.	*Dendrelaphis formosus*	Elegant Bronzeback	Co	R	
25.	*Dendrelaphis pictus*	Painted Bronzeback	Co	R	
26.	*Dogania subplana*	Forest Soft-shelled Turtle	En	R, FS	ReR
27.	*Draco melanopogon*	Black-bearded Flying Dragon	Fc	R, FS	
28.	*Draco volans*	Common Flying Dragon	Co	R	

B. Reptiles

No.	Species	Common Name	CS	SS	SR
29.	*Dryocalamus subannulatus*	Saddled Tree Snake	En	R, FS	ReR
30.	*Dryophiops rubescens*	Keel-bellied Whip Snake	En	R, FS	
31.	*Elaphe flavolineata*	Common Racer	Fc	R	
32.	*Gehyra mutilata*	Four-clawed Gecko	Co	R	
33.	*Gekko monarchus*	Spotted House Gecko	Fc	R	
34.	*Gekko smithi*	Large Forest Gecko	Un	R, FS	
35.	*Gonyosoma oxycephala*	Red-tailed Racer	En	R, FS	
36.	*Hemidactylus frenatus*	Common House Gecko	Co	R	
37.	*Hemiphyllodactylus typus*	Dwarf Gecko	En	R, FS	
38.	*Heosemys spinosa*	Spiny Terrapin	Un	R, FS	
39.	*Homalopsis buccata*	Puff-faced Water Snake	Fc	R	
40.	*Liopeltis baliodeirus*	Orange-bellied Ringneck	Ra	R, FS	
41.	*Lipinia* cf. *vittigera*	Yellow-striped Skink	En	R, FS	D
42.	*Lygosoma sp.*	Supple Skink A	?En	R, ?LS	?D
43.	*Mabuya multifasciata*	Common Sun Skink	Co	R	
44.	*Mabuya rugifera*	Striped Sun Skink	En	R, FS	
45.	*Macropisthodon rhodomelas*	Blue-necked Keelback	Fc	R	
46.	*Maticora bivirgata*	Blue Malayan Coral Snake	Un	R	
47.	*Maticora intestinalis*	Banded Malayan Coral Snake	Un	R	
48.	*Naja sumatrana*	Black Spitting Cobra	Co	R	
49.	*Notochelys platynota*	Malayan Flat-shelled Terrapin	En	?R	
50.	*Oligodon octolineatus*	Striped Kukri Snake	Fc	R	
51.	*Oligodon signatus*	Barred Kukri Snake	En	R, FS	
52.	*Ophiophagus hannah*	King Cobra	En	R	
53.	*Ophites aulicus*	Common Wolf Snake	Co	R	
54.	*Ophites subcinctus*	Banded Wolf Snake	En	R, FS, LS	ReR
55.	*Pelodiscus sinensis*	Chinese Soft-shelled Turtle		FE	
56.	*Psammodynastes pictus*	Painted Mock Viper	En	R, FS, LS	ReR
57.	*Pseudorhabdion longiceps*	Dwarf Reed Snake	Fc	R	
58.	*Ptyas carinatus*	Keeled Rat Snake	Co	R	
59.	*Ptyas korros*	Indo-Chinese Rat Snake	Fc	R	
60.	*Python reticulatus*	Reticulated Python	Co	R	
61.	*Ramphotyphlops braminus*	Common Blind Snake	Co	R	
62.	*Rhadophis subminiatus*	Red-necked Keelback	En	R, FS, LS	R
63.	*Riopa bowringi*	Garden Supple Skink	Co	R	
64.	*Sibynophis melanocephalus*	Black-headed Collared Snake	Un	R	
65.	*Siebenrockiella crassicollis*	Black Marsh Terrapin	Co	R	
66.	*Trachemys scripta*	Red-eared Terrapin		FE	
67.	*Tropidolaemus wagleri*	Wagler's Pit Viper	Ra	R, FS	
68.	*Varanus nebulosus*	Clouded Monitor	Fc	R, FS	
69.	*Varanus salvator*	Malayan Water Monitor	Co	R	
70.	*Xenelaphis hexagonotus*	Malayan Brown Snake	Un	R	
71.	*Xenochrophis maculatus*	Spotted Keelback	Ra	R, FS	ReR
72.	*Xenochrophis piscator*	Chequered Keelback		FE, FS, LS	
73.	*Xenochrophis trianguligerus*	Triangle Keelback	En	R, FS, LS	R

B. Reptiles

No.	Species	Common Name	CS	SS	SR
74.	*Xenopeltis unicolor*	Sunbeam Snake	Fc	R	
75.	*Zaocys fuscus*	White-bellied Rat Snake	En	R, FS, LS	R

C. Amphibians

No.	Species	Common Name	CS	SS	SR
1.	*Bufo melanostictus*	Asian Toad	Co	R	
2.	*Bufo quadriporcatus*	Four-ridged Toad	En	R, FS	ReD
3.	*Ichthyophis* cf. *paucisulcus*	Yellow-banded Caecilian	En	R, FS	
4.	*Kalophrynus pleurostigma*	Black-spotted Sticky Frog	Un	R, FS	
5.	*Kaloula pulchra*	Banded Bullfrog	Co	FE	
6.	*Leptobrachium nigrops*	Black-eyed Litter Frog	Fc	R, FS	
7.	*Limnonectes blythii*	Malayan Giant Frog	Fc	R, FS	
8.	*Limnonectes malesiana*	Malesian Frog	Un	R, FS	
9.	*Limnonectes paramacrodon*	Masked Swamp Frog	Ra	R, FS	ReD
10.	*Megophrys nasuta*	Malayan Horned Frog	En	R, FS	
11.	*Microhyla borneensis*	Bornean Narrow-mouthed Frog	En	R, FS, LS	D
12.	*Microhyla butleri*	Painted Narrow-mouthed Frog	Co	R	
13.	*Microhyla heymonsi*	Dark-sided Narrow-mouthed Frog	Co	R	
14.	*Nyctixalus pictus*	Spotted Tree Frog	Ra	R, FS	
15.	*Occidozyga laevis*	Smooth Puddle Frog	Fc	R, FS	
16.	*Pelophryne brevipes*	Saint Andrew's Cross Toadlet	En	R, FS, LS	ReR
17.	*Polypedates leucomystax*	Common Tree Frog	Co	R	
18.	*Rana baramica*	Masked Rough-sided Frog	Un	R, FS	
19.	*Rana cancrivora*	Crab-eating Frog	Co	R	
20.	*Rana chalconota*	Copper-cheeked Frog	Co	R, FS	
21.	*Rana erythraea*	Common Greenback	Co	R	
22.	*Rana glandulosa*	Rough-sided Frog	Ra	R, FS	D
23.	*Rana limnocharis*	Field Frog	Co	R	
24.	*Rana plicatella*	Rhinoceros Frog	Ra	R, FS	
25.	*Rhacophorus bimaculatus*	Blue-legged Tree Frog	En	R, FS, LS	R
26.	*Theloderma horridum*	Thorny Bush Frog	En	R, FS, LS	D

Plate 1a. Lee King Li

Plate 1b. Shirley Pottie

Plate 1c. Lee King Li

Plate 1d. Robert Teo

Plate 1. Some of the endangered mammals found in the Nature Reserves. a. *Penthetor lucasi* (Dusky Fruit Bat). **b.** *Nycteris tragata* (Hollow-faced Bat). **c.** *Rhinolophus trifoliatus* (Trefoil Horseshoe Bat). **d.** *Rhinolophus luctus* (Great Woolly Horseshoe Bat).

Plate 2a. Robert Teo

Plate 2. A new discovery at Bukit Timah Nature Reserve. a. *Hylopetes spadiceus* (Red-cheeked Flying Squirrel).

Plate 3a. Lee Kong Li

Plate 3b. Robert Teo

Plate 3c. Lee Kong Li

Plate 3d. Robert Teo

Plate 3e. Robert Teo

Plate 3. Some of the endangered reptiles found in the Nature Reserves. a. *Dryocalamus subannulatus* (Saddled Tree Snake). **b.** *Xenochrophis trianguligerus* (Triangle Keelback). **c.** *Cosymbotes craspedotus* (Frilly Gecko). **d.** *Cyrtodactylus* cf. *consobrinus* (Banded Bent-toed Gecko). **e.** *Dogania subplana* (Forest Soft-shelled Turtle).

Plate 4a. Lee King Li

Plate 4b. Lee King Li

Plate 4c. Lee King Li

Plate 4d. Leong Tzi Ming

Plate 4. Rare (a–b) and endangered (c–d) amphibians found in the Nature Reserves. a. *Limnonectes paramacrodon* (Masked Swamp Frog). **b.** *Rana glandulosa* (Rough-sided Frog). **c.** *Theloderma horridum* (Thorny Tree Frog). **d.** *Microhyla borneensis* (Bornean Narrow-mouthed Frog).

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