The Vegetation in the Nature Reserves of Singapore

RICHARD T. CORLETT
Department of Ecology & Biodiversity
University of Hong Kong
Pokfulam Road
Hong Kong, China

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 secondary 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" \( \text{[Imperata cylindrica]} \).

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
less, migratory

...t in isolated areas of various ha], and of no average a quarter [1.6 km]. The...ng" [Imperata

cluded in forest (Corlett, 1995a).

have received nature reserves cultivation and forest, which Subsequently, recreational and 1).

ibed by Corlett of the current

nical collecting Ridley (1900), species continue (Ali Ibrahim Forest angiosperm Reserve since vascular flora (Nature Reserve) survive today, vascular plant in Singapore id been cleared uring the forest only about one

 ![Vegetation](image)

**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/Champeriea community, and the Eugenia/Arthrophyllum community, respectively.
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 fusc, Annonaceae) and/or pneumatophores of various types (plank-like in Lophopetalum multinervium, Celastraceae) illustrated in Corner (1978),
ong the large
ature Reserve
Wyatt-Smith
Hill can be
ance of Shorea
1987; Swan,
to that of
her prominent
al members of
yera costulata
thes icosandra
Mangifera
ees and shrubs
and Rubiaceae.
derected
Calamus,
ly abundant at
in the central
limbers are the
1, Apocynaceae
erris, Entada,
cal families of
sity is low in
1 types (Turner

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 (*Lisea*), with *Camptospermum auriculatum* (Anacardiaceae), *Elaeocarpus* spp. (Elaeocarpaceae), *Gynotroches axillaris* (Rhizophoraceae), *Ixsantheres reticulata* (Ixobataceae) and *Timonium wallichianum* (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* (Melastomataceae), *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
components are ending pioneers, uphorbiaceae), inc on aerial
At the other tree crowns are inated. At this lies Myrtaceae (sarcinio), and
(troacardia), ziziphoraceae), wallichianus (Myrtaceae) in
lerata grassland

At the other tree crowns are inated. At this lies Myrtaceae (sarcinio), and
(troacardia), ziziphoraceae), wallichianus (Myrtaceae) in
lerata grassland

Acknowledgments
A comprehensive list of those who have contributed to this paper would exceed the limits of editorial tolerance, but I would like to offer special thanks to P.T. Chew, H.T.W Tan, I.M. Turner, J.V. LaFrankie, F.R. Swan, D.H. Murphy, Ali bin Ibrahim, and Haji Samsuri bin Haji Ahmad.
References


