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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 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" [*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

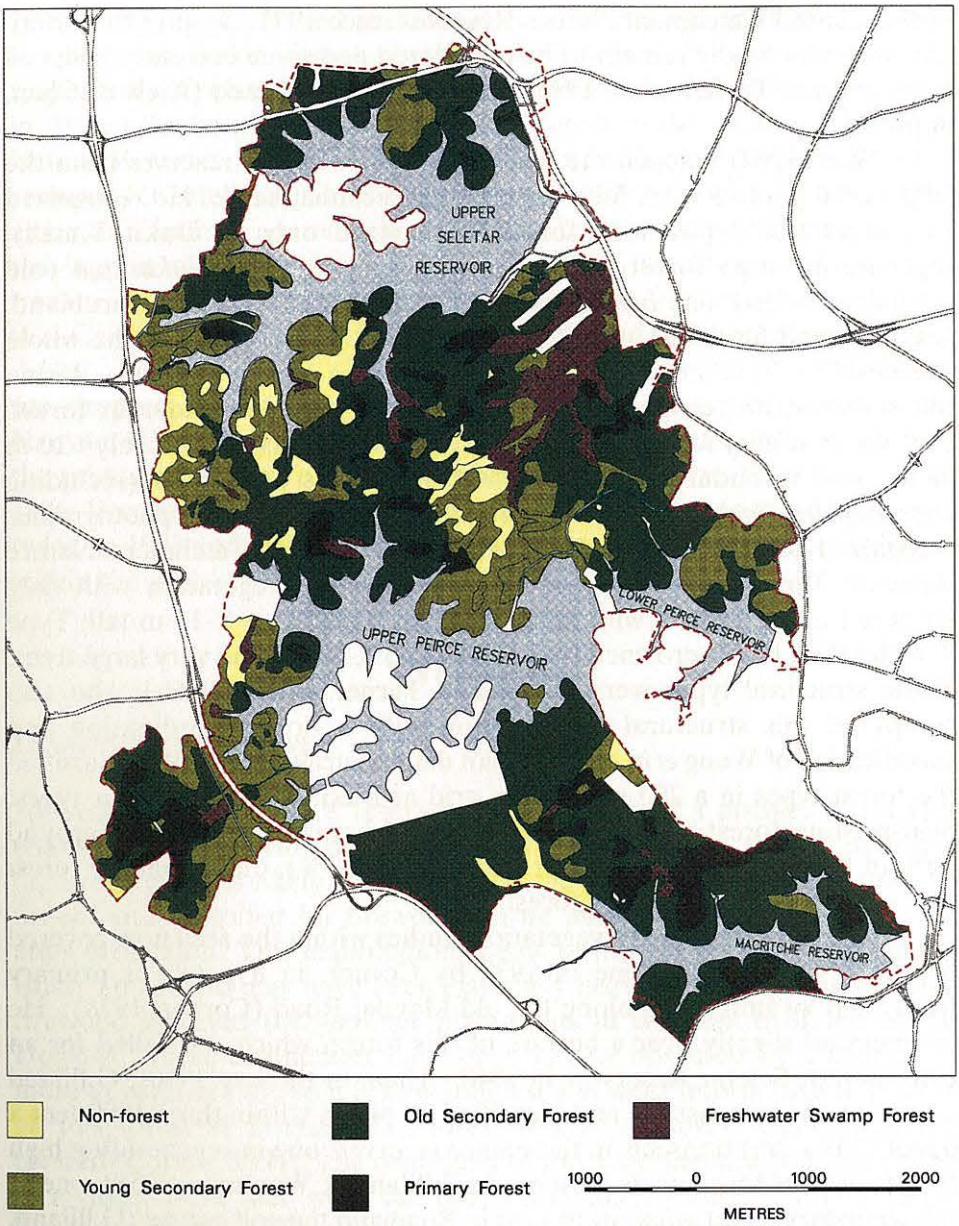

Figure 1. Map of the Nature Reserves showing the major vegetation types.

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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