CHAPTER 5

Rifle Range Nature Park: Restoration of Two Ecosystems

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Rifle Range Nature Park (RRNP) is a 66-hectare nature park located at the southern end of Bukit Timah Nature Reserve (Fig. 1). The park serves as an important buffer to the Bukit Timah Hill, Singapore's highest hill, which remains one of the few areas of primary rainforest and the home to around 40% of Singapore's native flora and fauna in the country.

As a buffer park, RRNP provides not only habitat for native fauna but also food sources for them to survive on. Habitat restoration is pivotal for the development of this park, which is part of a holistic approach to strengthen biodiversity conservation in Singapore's nature reserves while providing interesting alternative venues for the public to enjoy nature-related activities in a highly urbanised city-state.

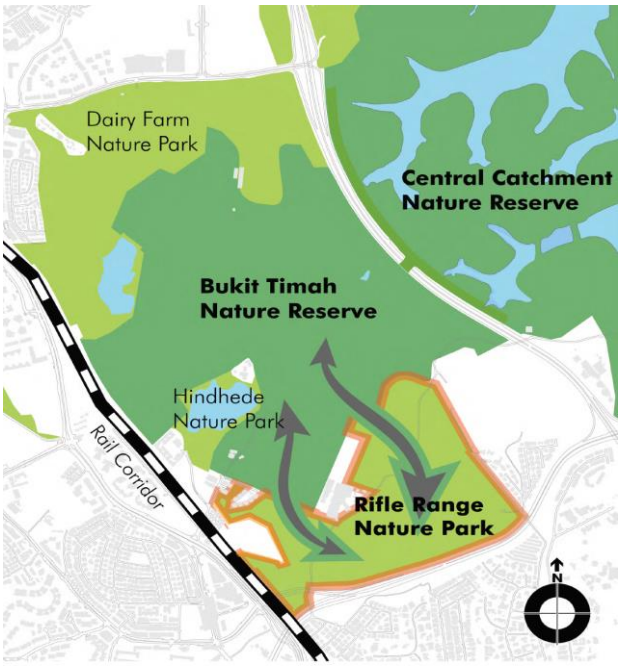


Fig. 1. Map showing the link between Bukit Timah Nature Reserve and Rifle Range Nature Park.

The key challenges for this nature-sensitive project were to: 1) find a balance between the development of recreation uses and conservation of biodiversity through habitat restoration and 2) integrate a data-driven, science-based approach at all stages of the park development process.

Guiding principles

A clear goal of restoration

From the early stages of the park's planning, the goal of restoring its natural historical ecosystem was established as central to the project. Historically, the site was a granite hill with secondary forests, villages, and quarrying activities from the 1950s to the 1980s. By the 1990s, quarrying activities stopped, and the quarry was backfilled. Villagers were also resettled due to the quarry's closure. With decades of undisturbed period and minimal human intervention, some species of flora and fauna from the Bukit Timah Nature Reserve have re-established themselves in the Nature Park. The clear goal of restoration served as an important guide in the making of the nature park so that decisions to protect ecological habitats were prioritised over recreational needs.

Data-driven design and planning

The planning and design of RRNP were based on scientific data. Before designing of the park in the existing forest commenced, areas of high biodiversity and significant large trees with high conservation value needed to be identified and protected. Hence, a nine-month-long biodiversity study was commissioned to document and map out the floristic and fauna diversity. The study entailed line-transect surveys of over 10 kilometres conducted by systematically walking the site and recording sightings for flora and fauna, plot sampling, and deployment of over 110 camera traps strategically placed within the site. The camera traps were programmed to be active 24 hours per day at high sensitivity to collect video footage when triggered by movement or changes in temperature. The detailed baseline study at the planning stage was fundamental for the subsequent design and implementation of the park.

Site history

The land at RRNP had been left to regenerate for approximately 30 years. The majority of the site was covered by young secondary forest and scrubland appearing to be degraded due to the lack of large, tall trees and a closed-canopy layer, the widespread presence of exotic and weedy vegetation, the open understorey, and large areas of muddy soil. Scattered throughout the site were vestiges of kampung settlements, in the form of cultivated vegetation, concrete foundations, roads and paths, pottery and other curios, and lastly, trash.

One of the biggest disturbances to the site was Sin Seng Quarry. Shut down and backfilled in the 1990s, the site of the quarry remained barren until 2003. Scrubs and weeds infiltrated the area. The

quarry site was largely covered by ferns and pitcher plants, both indicators of high light penetration and poor soil conditions.

Two streams flow through RRNP. The source for one stream is from Bukit Timah Nature Reserve. The other stream, which begins as a pond adjacent to Murnane Reservoir and flows south to the Pan-Island Expressway, also has a tributary at its southern end which stretches to Jalan Kampong Chantek.

Baseline information

Based on the vegetation mapping carried out from March 2017 to March 2018, RRNP comprised largely secondary forest from abandoned plantations and several kampung (64%), followed by scrubland/herbaceous vegetation (24%), managed vegetation (4.4%), native-dominated low secondary forest (4.3%), waste-woodlands (Fig. 2) (1.7%), stream vegetation (0.7%), swampland (0.2%) and pond vegetation (Yee *et al.*, 2016). The flora survey recorded a total of 401 species of vascular plants from 106 families of which there were 184 species of trees, 127 species of shrubs/herbs and 90 species of climbers (unpublished report: Baseline survey of RRNP, 2018, carried out by Camphora Pte. Ltd.).

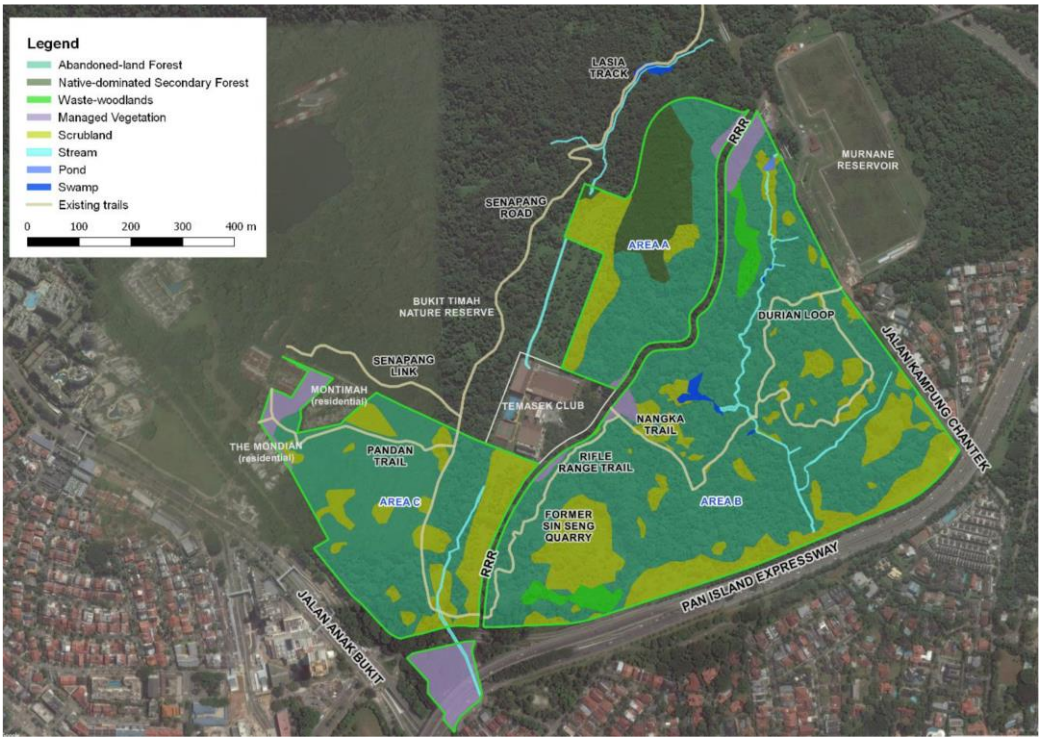


Fig. 2. Map illustrating the various vegetation types identified at Rifle Range Nature Park. (Image credit: Camphora Pte. Ltd.)

The fauna transect surveys and live-trapping recorded 288 species, consisting of 36 odonate, 87 butterfly, seven fish, four decapod crustacean, 56 herpetofauna, 79 bird, and 19 mammal species including the Sunda Pangolin (*Manis javanica*) and Leopard Cat (*Prionailurus bengalensis*), which are critically endangered locally.

The results of the study guided the restoration of natural habitats, informed the design of the nature park and ensured that the implementation of works was done sensitively and sustainably. The work included several ecological enhancements such as habitat enhancement, implementation of wildlife connectivity features and incorporation of sustainability elements in the park design. Based on the preliminary findings, recommendations focussed on the creation of ecological habitats and connectivity, as well as enhancement of stream and fauna habitats.

Implementing habitat restoration

NParks' Forest Restoration Action Plan (FRAP) was drawn to operationalise the Nature Conservation Masterplan. It was formulated to chart the restoration initiatives that would be undertaken over 10 years to regenerate the secondary forests in the buffer parks surrounding the Bukit Timah and Central Catchment Nature Reserves, as well as disturbed patches within the Reserves.

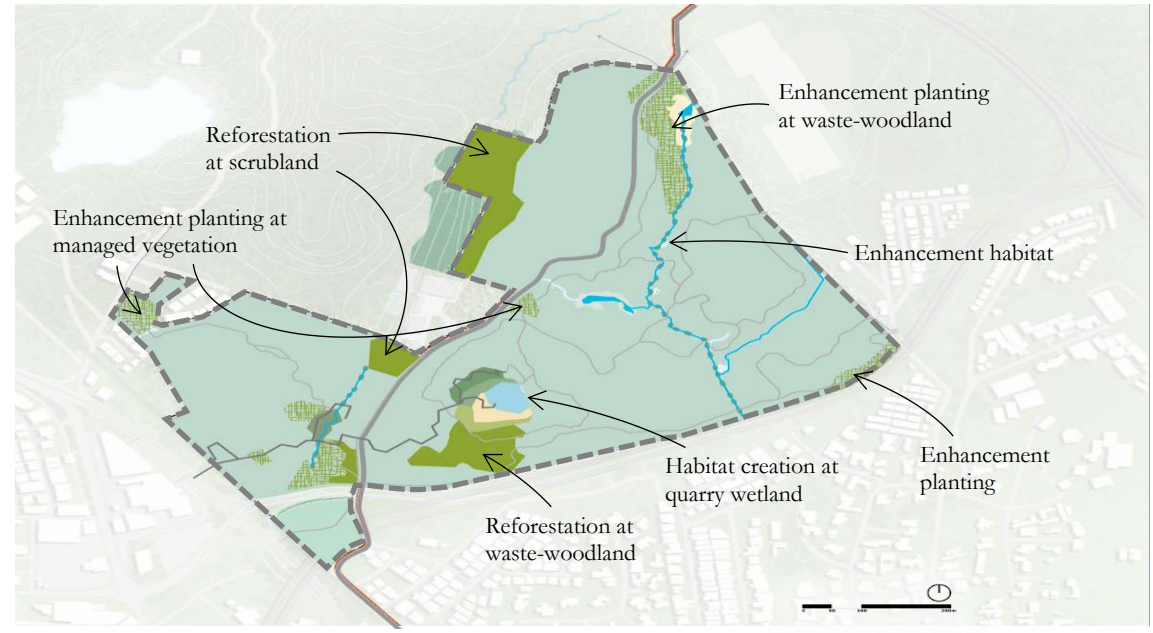


Fig. 3. Map showing targeted habitat restoration methods. (Image credit: Henning Larsen Pte. Ltd.)

NParks applies a combination of three forest regeneration techniques to assist the forests to evolve into a mature forest landscape over time. The habitat restoration sites in RRNP identified jointly by NParks, Camphora Pte. Ltd., and Henning Larson Pte. Ltd. are shown in Fig. 3.

General principles used

1) Maximal Species Diversity

Dominant primary rainforest species that may be limited by dispersal or are rare in occurrence, were introduced (Annex I). The seedlings of such species are adapted to shade conditions and depend on the canopy of the secondary forests in the nature parks to establish themselves.

2) Framework Species Method

A framework of native leguminous tree species and fruit-bearing tree and shrub species is introduced as indicated below:

These species (Annex II) fix nitrogen in the soil and attract animals and insects which assist with seed dispersal and pollination. Over time, the soil condition improves and enables more native species to be naturally dispersed into the regenerating forests from the Nature Reserves. This technique is used to restore main areas of scrubland.

3) Assisted Natural Regeneration

Exotic weeds (e.g., *Dioscorea sansibarensis*, *Falcataria moluccana*, *Spathodea campanulata*, and *Leucaena leucocephala*) that compete with native tree species in forest regeneration are removed.

This is sensitively implemented over time to avoid impacting habitats provided by some of these species. To restore smaller areas of scrubland, this method is most appropriately carried out by marking and protecting the native seedlings.

Key habitats restored

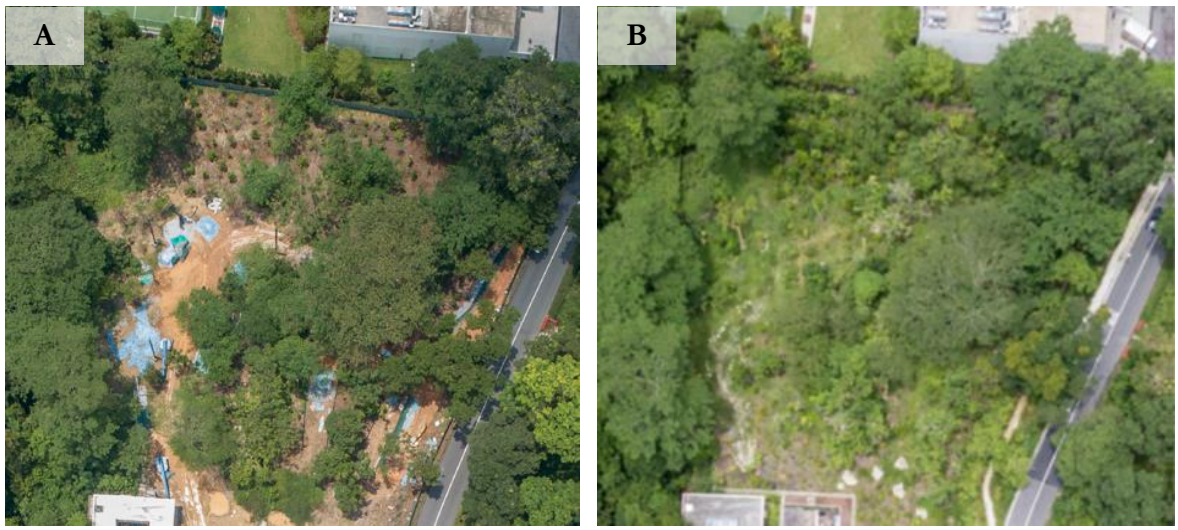
Forest habitat

Kampung vegetation was retained as it served as the key framework providing food source and home to the resident fauna recorded here. The maximal species diversity was applied with the planting of native species saplings. Most of the large trees with girth size greater than 1.5 metres

were kept. These large trees included *Durio zibethinus*, *Nephelium lappaceum*, *Ficus vasculosus*, *Palaquim gutta*, and *Xanthophyllum obscurum*.

Native species planted included legumes, such as Petai (*Parkia speciosa*), fruit-bearing trees such as the Common Sterculia (*Sterculia parviflora*) and the Kumpang (*Horsfieldia polyspherula*), and pollinator-attracting trees such as the Pulai Penipu Paya (*Alstonia angustifolia*). This would ensure species recovery by increasing the amount of native flora for native wildlife in the area.

In large open areas, framework species comprised a mixture of emergent trees, canopy trees and understory trees and shrubs. Fast growing species that would shade out weeds and fruit-bearing trees were included to attract seed dispersers. This involved the planting of nitrogen-fixing native species *Koompassia malaccensis* and *Parkia speciosa* that would naturally improve the soil condition, as well as attract dispersers and pollinators. Dominant primary rainforest species, which were limited by dispersal or were rare in occurrence, were also introduced, e.g., *Dipterocarpus kunstleri*, *Dipterocarpus cornutus*, *Dipterocarpus costulatus*, etc. These were selected for this site as they were found in the nature reserves.



Figs. 4. (A) A Reforestation Corridor taken in April 2021 just after planting; (B) Reforestation Corridor 18 months later, October 2022.

As in all open areas and forest edges, the weeds and climbers established rapidly and smothered these plants, such as *Dioscorea sansibarensis*, which was difficult to eradicate. Regular removal of this climber on these newly planted sites was carried out to prevent it from spreading and inhibiting the growth of the saplings.

This helped the forest to establish and enhance the nature park's biodiversity and ecological connectivity, as well as strengthen the resilience of the forests to climate change. Fig. 4A and 4B show how the site had changed over an 18-month period as a result of habitat restoration.

Wetlands habitat

The former Sin Seng Quarry, once one of Singapore's deepest quarries at 55 metres deep, had been filled with soil during the late 1990s and over the years, it had become an open scrubland where exotic species were seen to be colonising. As part of the habitat restoration of RRNP, this was enhanced as a freshwater habitat based on the schematic approach designed jointly by NParks, Camphora Pte. Ltd., and Henning Larson Pte. Ltd. shown in Fig. 5.

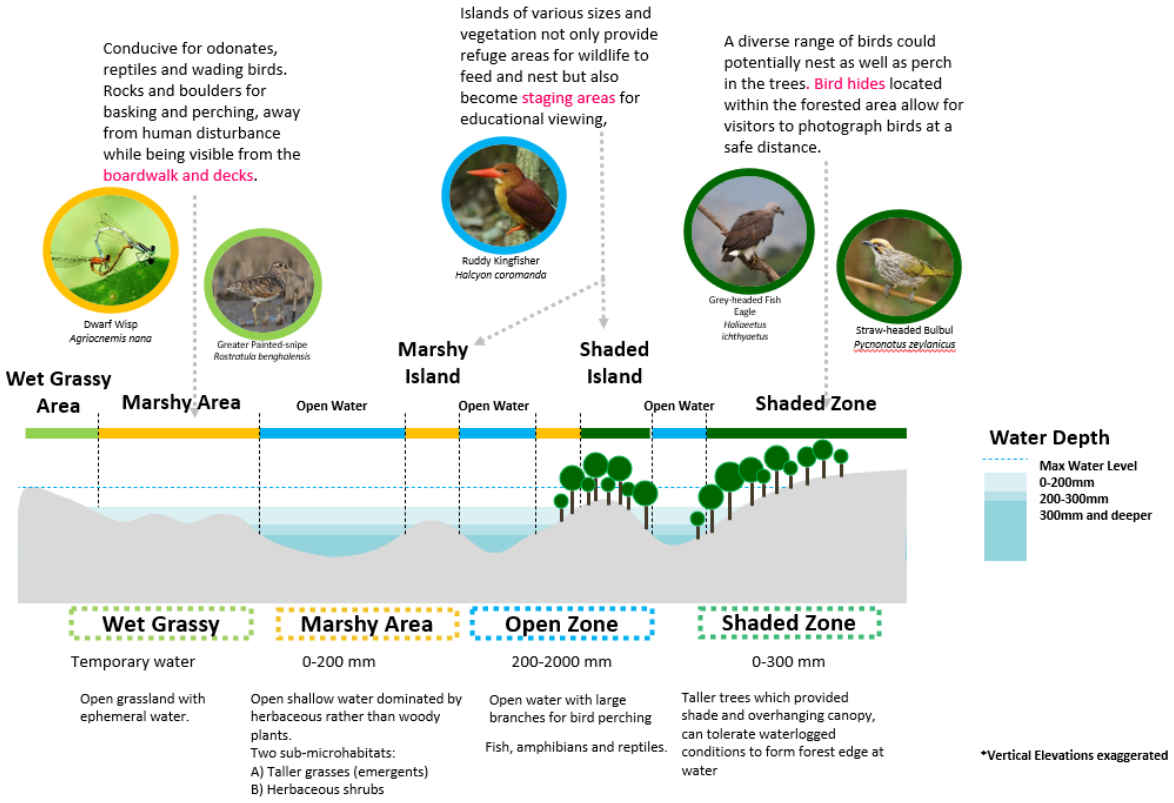


Fig. 5. A schematic drawing on the restoration of a wetland habitat. (Image credit: Henning Larsen Pte. Ltd.)

The restoration of the freshwater wetland ecosystem improved the water quality and provided habitats for wetland animals and migratory birds such as the Blue Percher (*Diplacodes trivialis*), Yellow Bittern (*Ixobrychus sinensis*) and Malayan Water Monitor (*Varanus salvator*) (Fig. 6).

Fig. 6. Freshwater habitat at the Quarry Wetland.

At the open water area, emergent, floating, and submerged plants were introduced. Mainly small clusters of Water Snowflake (*Nymphoides indica*) and dense hedges of *Lepironia articulata* were planted.

Closer to the water edge, species including Leather Fern (*Acrostichum aureum*), *Alocasia longiloba*, aquatic ginger (*Alpinia aquatica*), and Chinese Water Chestnut (*Eleocharis dulcis*) were planted.

The banks, comprising largely of marshy and wet grasslands, were dominated by *Dillenia suffruticosa*. These areas were enhanced with the planting of water-tolerant shrubs, herbs, and climbers including Slender Pitcher Plant (*Nepenthes gracilis*), Finlayson's Bromheadia (*Bromheadia finlaysoniana*) and Bamboo Orchid (*Arundina graminifolia*), *Spathoglottis plicata*, *Alocasia longiloba*, Love Grass (*Eragrostis unioloides*), and Sword Fern (*Nephrolepis biserrata*), Singapore Rhododendron (*Melastoma malabathricum*) and Climbing Fern (*Stenochlaena palustris*).

At the shaded area, existing trees were kept, and enhancement planting were carried out. Water-tolerant trees species were planted to provide canopy cover. These include Mempat (*Cratoxylum formosum* and *Cratoxylum cochinchinense*), Marsh Pulai (*Alstonia spatulata* and *Alstonia pneumatophora*), Stilted Simpoh (*Dillenia recticulata*), Lipstick Palm (*Cyrtostachys renda*), and Tree Fern (*Alsophila latebrosa*).

Community involvement

Initiating nature-sensitive programmatic planning for RRNP is important to engage, educate, and involve communities to help with nature conservation. One such programme is the Invasive Species Management (ISM), which involves residents and the nature community to help weed out invasive alien species that pose an ever-increasing threat if left unmanaged. This would facilitate habitat restoration.

During fruiting seasons, especially masting, seeds are collected and propagated in the Community Nursery built at the park. This ensures that the native gene stocks are conserved for replenishing the plant populations at RRNP. Volunteers from the community can help with the propagation of native plants that are used in restoring and enhancing the different ecosystems found in RRNP.

The RRNP Community Nursery will specialise in the propagation of native pioneer and secondary forest species to be planted in RRNP under FRAP. Nature parks act as ecological buffers and provide complementary habitats for flora and fauna in the nature reserves. As part of NParks' efforts to expand our natural capital, native tree species that support local fauna will be propagated and planted out to enhance the habitats in the regenerating forests of various nature parks. Annex III lists more comprehensively the flora species planting palette that has been carefully selected for planting within RRNP for general habitat restoration.

Conclusions

RRNP is one of the efforts to operationalise FRAP that is integral to NParks' habitat enhancement and restoration programme. It is one of the key thrusts of NParks' Nature Conservation Masterplan that was launched in 2015 to chart Singapore's plans for biodiversity conservation.

For nature sensitive development, there is a delicate balance between the development of recreation uses and conservation of biodiversity. Besides habitat enhancement, the design features of RRNP are closely integrated with biophilic design elements to encourage people's well-being and human-nature interactions. The design of the trails is also user-centric offering an inclusive and unique visitor experience of harmony with nature. One of the popular trails is the trail leading to the Wetlands Quarry and the Colugo Deck, inspired by the silhouette of a Sunda Colugo.

Community stewardship is key to protecting our native flora and fauna. Through guided walks, NParks reaches out to the public to learn more about our native wildlife. By participating in ISM and the plant propagation programme, people can gain a better understanding of the efforts in conservation.

Since its launch on 12 November 2022, RRNP has shown that habitat restoration reaps multiple benefits, with faunal records increasing to 300. Habitat restoration will only work out well when the site is protected and properly managed sustainably and ecologically on a long-term basis with compatible development carried out sensitively in its vicinity (Fig. 7). Wildlife has benefitted from the restoration as faunal records have increased to 300.

Restoration is futile without reasonable assurance that the project site will be protected and properly managed sustainably and ecologically on a long-term basis with compatible development carried out sensitively in its vicinity.

Fig. 7. View of RRNP from the top of Colugo Trail.

References

Yee ATK, Chong KY, Neo L & Tan HTW (2016) Updating the classification system for the secondary forests of Singapore. Raffles Bulletin of Zoology Supplement, 32: 11–21.

Annex I: Dominant primary rainforest species which might be limited by dispersal or are rare in occurrence

Aquilaria malaccensis
Dialium indum
Dillenia grandifolia
Dillenia reticulata
Dipterocarpus cornutus
Dipterocarpus costulata
Dipterocarpus grandiflorus
Dipterocarpus kunstleri
Dyera costulata
Hopea ferruginea
Hopea griffithii
Hopea mengarawan
Hopea sangal
Intsia palembanica
Knema curtisii
Koompassia malaccensis
Parishia insignis
Parkia speciosa
Pentace triptera
Rhopaloblaste singaporensis
Scaphium macropodum
Shorea curtisii
Shorea leprosula
Shorea macroptera
Trigonaches acuta
Vatica odorata
Xanthophyllum ellipticum

Annex II: Leguminosae family, with nitrogen fixing properties

Archidendron bubalinum (*Albizzia spendens*)
Archidendron clypearia
Archidendron jiringa
Cynometra ramiflora
Dialium indum
Intsia palembanica
Koompassia malaccensis
Parkia speciosa
Sindora wallichii

Annex III: Comprehensive planting palette used for RRNP

Trees and palms

Alsophila latebrosa
Alstonia spatulata
Aporosa penangensis
Aquilaria malaccensis
Archidendron bubalinum (*Albizzia spendens*)
Archidendron clypearia
Archidendron jiringa
Ardisia elliptica
Artocarpus elasticus
Baccauarea brevipes
Baccauarea motleyana
Barringtonia racemosa
Barringtonia reticulata
Bouea macrophylla
Bouea oppositifolia
Buchanania arborescens
Calophyllum soulattri
Campnosperma auriculata
Carallia brachiata
Caryota mitis
Cleistanthus malaccensis
Cratoxylum cochinchinense
Cratoxylum formosum
Cratoxylum maingayi
Cynometra ramiflora
Cyrtophyllum fragrans
Cyrtostachys renda
Dialium indum
Dillenia excelsa
Dillenia grandifolia
Dillenia indica
Dillenia reticulata
Dillenia suffruticosa
Diospyros buxifolia
Diospyros lanceifolia
Dipterocarpus cornutus
Dipterocarpus costulata
Dipterocarpus grandiflorus
Dipterocarpus kunstleri
Dracaena maingayi
Dyera costulata
Elaeocarpus mastersii
Elaeocarpus petiolatus
Eleiodoxa conferta
Eurycoma longifolia
Ficus consociata
Ficus macrocarpa
Ficus microcarpa
Ficus variegata
Flacourtia rukam
Garcinia atroviridis
Garcinia hombroniana
Garcinia parviflora
Garcinia prainiana
Gardenia tubifera
Gnetum gnemon
Gynotroches axillaris
Heritiera simplicifolia

Trees and palms *(Cont'd)*

Hopea ferruginea
Hopea griffithii
Hopea mengarawan
Hopea sangal
Horsfieldia irya
Horsfieldia polyspherula
Horsfieldia superba
Iguanura wallichiana
Ilex cymosa
Intsia palembanica
Knema curtisii
Koompassia malaccensis
Korthalsia sp.
Leea angulata
Lepisanthes rubiginosa
Licuala ferruginea
Litsea elliptica
Mangifera caesia
Mangifera foetida
Maranthes corymbosa
Memecylon caeruleum
Memecylon pauciflorum
Neolitsea cassia / N. zeylanicum
Ochanostachys amentacea
Oncosperma tigilarium
Palaquium gutta
Palaquium obovata
Pandanus atrocarpus
Parishia insignis
Parkia speciosa
Pentace triptera
Phyllanthus emblica
Ploiarium alternifolium
Pometia pinnata
Pouteria obovata
Pteleocarpa lamponga
Radermanchera quadripinnata
Rhopaloblaste singaporensis
Sandoricum koetjape
Scaphium macropodum
Shorea curtisii
Shorea leprosula
Shorea macroptera
Sindora wallichii
Steblus elongatus
Sterculia cordata
Sterculia parviflora
Sterculia rubiginosa
Streblus elongatus
Suregada multiflora
Syzygium borneensis
Syzygium carasiforme
Syzygium glaucum
Syzygium lineatum
Syzygium myrtifolium
Syzygium polyanthum
Syzygium singaporense
Syzygium syzygioides
Syzygium zeylanicum
Tarenna odorata

Trees and palms *(Cont'd)*

Trigonaches acuta
Vatica odorata
Xanthophyllum ellipticum

Shrubs and ground covers

Acrostichum aureum
Agrostistachys borneensis
Alocasia longiloba
Alpinia aquatica
Alpinia conchigera
Angiopteris evecta
Ardisia crenata
Arundina graminifolia
Asplenium longissimum
Asplenium nidus
Blechnopsis orientalis
Blechnum finlaysonianum
Bromheadia finlaysoniana
Cayratia mollisima
Centotheca lappacea
Cheilocostus speciosus
Chonemorpha fragrans
Clerodendrum inerme
Clerodendrum laevifilium
Crinum asiaticum
Cyathula prostata
Cyclosorus polycarpus
Cymbopogon citratus
Cyperus alternifolius
Davalia denticulata
Dianella ensifolia
Donax canniformis
Dracaena porteri
Eleocharis dulcis
Eragrostis unioloides
Ficus apiocarpa
Ficus deltoidea
Ficus recurva
Flacourtia rukam
Flagellaria indica
Freycinetia javanica
Gardenia tubifera
Gomphandra quadrifida
Grammatophyllum speciosum
Hydrocotyle sibthorpioides
Ipomea pes caprae
Ixora congesta
Ixora lobbii
Kopsia singapurensis
Lasia spinosa
Leea indica
Leea rubra
Lepironia articulata
Licuala spinosa
Loeseneriella macrantha
Melanthera biflora
Melastoma malabathricum

Shrubs and ground covers *(Cont'd)*

Memecylon ovatum

Microchites serphllifolius

Microsorum scolopendria

Molinera capitulata

Molinera latifolia

Mucuna biplicata

Nenga pumila var.polystachya

Nepenthes gracilis

Nephrolepis biserata

Nephrolepsis falcata

Nymphoides indica

Pandanus pygmaeus

Pellionia repens

Phanera semibifida

Phymatosorus scolopendria

Pinaga disticha

Piper sarmentosum

Pityrogramma calomelanos

Poikilospermum sp.

Premna serratifolia

Psychotria maingayi

Pteris semipinnata

Rhodomyrtus tomentosa

Rothmannia macrophylla

Sauropus androgynus

Schismatoglottis calyptrata

Schumannianthus dichotomus

Scindapsus pictus

Selaginella sp.

Selaginella wildenowii

Spathoglottis plicata

Stenochlaena palustris

Tabernaemontana corymbosa

Tarenna fragra

Tectaria singaporiana

Tetracera indica

Thottea grandiflora

Tristellateia australasiae

Vanilla griffithii