Introduction to Plant Life on Kent Ridge

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September 5, 2004

1 *Adinandra* Belukar

The type of vegetation on the Ridge is known as *Adinandra* belukar. The name comes from two sources: *Adinandra* dumosa is the scientific name of the tree most commonly found in this type of vegetation, while 'belukar' is the Malay word for 'secondary forest'. Secondary forest refers to forest that grows on ground that has been previously cleared of its original natural vegetation (known as primary forest), or that has been significantly disturbed. It is different from primary forests in many ways. Different physical conditions include increased light intensity, lower humidity, and higher temperatures. Because the physical conditions are different, different species that are better adapted to these conditions thrive in them. Furthermore, the diversity of plants and animals found in secondary forests is much less than that in primary forests. In order to survive and be successful, plants in secondary forests also have to grow quickly and be easily and widely dispersed, so that they may colonize newly disturbed ground before other plants do. *Adinandra* belukar is found on degraded land, whereas another type of belukar, *Trema* belukar, dominated by *Trema* species and similar plants, is found in naturally occurring gaps in primary forest, where the soil is still rich in nutrients and not degraded.

Belukar has several distinct differences from primary forest. First, its plant diversity is much lower, with less plants species per unit area than primary forest. Second, temperature and humidity fluctuations are much greater. Belukar is highly exposed to the elements, hence in the day it is very warm and during the night it is very cool. It is much drier too, for the belukar's relative humidity averages 62% whereas primary forests experience at least 76% humidity. Third, the soil is much poorer, lacking various nutrients due to its previous uses as cultivated land. Rain and other erosive agents also wash away humus and organic material. In short, belukar is hotter, drier, and poorer than primary forests.

Further reading: *Adinandra* belukar was first qualitatively described by Holttum[26], and later by Sim et al[51]. Wee and Corlett[68] have given a semi-popular account of secondary vegetation in Singapore, and Corlett[18] has described the various stages of development in Singapore's secondary vegetation based on studies in the Central Catchment area.

2 Plant Overview

The dominant plant on the Ridge[51][26] is *Adinandra dumosa*, the Tiup Tiup, which is a small tree with reddish young leaves and small creamy white flowers.

Other common plants include:

- *Melastoma malabathricum*, the Singapore Rhododendron, that has pretty purple flowers and an edible dark purple fruit;
- *Ficus grossularioides*, a fig with leaves that show great variation in form, ranging from deeply lobed to an ellipse;
- *Myrica esculenta*, a small shrubby plant that has spirally arranged leaves;
- *Dillenia suffruticosa*, Simpoh Air (Ayer), a prominent plant that has large thick leaves, bright yellow flowers, and bright red star-shaped fruits; and
- *Rhodamnia cinerea*, the Silverback, so-called because the underside of its leaves are a glossy whitish colour.

A commonly seen tree that is not native but was introduced to the region is *Acacia auriculiformis*, a tree with a messy looking crown and sickle-shaped 'leaves' (that are actually modified stems or phylloclades) as well as abundant sprays of yellow flowers. It is a native of northern Australia, the Torres Straits, and southern Papua New Guinea[7]. Furthermore, there are several types of non-woody plants in the belukar. The most well-known are the species of *Nepenthes*, or the pitcher plants. They are insectivorous, trapping insects and other small creatures in their jug-like pitchers, which contain a liquid that has digestive enzymes, acting like a stomach to digest trapped animals for additional nutrients. The plant needs these extra nutrients because of the poor nutrient content of the soil. The ground-dwelling orchid *Bromheadia finlaysoniana* is also present on the ridge, bearing attractive pinkish flowers.

The Resam fern, *Dicranopteris linearis*, is very commonly seen. It is a sun loving fern that rapidly blankets large areas of bare land and prevents other plants from establishing themselves there. Resam is considered a harmful weed to agriculture, and drastic measures, like cutting it down flush to the ground and spraying the roots with lime, are needed to stop its growth and spread[40]. Epiphytes are conspicuously absent from the belukar. They are plants that grow on other plants, without tapping their hosts for nutrients. Hence they are not parasites, but only use their hosts as a support for growth. Before humans disturbed and cleared inland forests, these belukar plants were usually confined to limestone cliff forests and other similar harsh environments, which have conditions much like those found in belukar land[18]. After primary forests were disturbed, they were then able to colonise cleared land by dispersing from their original habitats.

3 Succession

Belukar plants are not usually found in primary undisturbed forest. In South East Asia, the forests are characterized by the presence of dipterocarps, members of the family Dipterocarpaceae, which is known for its winged seeds and good timber. They are large, imposing trees that grow slowly and reach great heights when mature, forming the structural backbone of the tropical forest. When these are cleared from the land, or when gaps appear in the forest, the plants that emerge to quickly take over the land are known as pioneers. As mentioned

above, they tend to grow quickly as well as flower and fruit often. They are also better dispersed than dipterocarps, hence pioneers can get to the open land faster than the dipterocarp seeds. The exposed nature of gaps and clearings ius also unsuitable for many primary forest plants, which have adapted to the humid and shaded climate of the understorey – the part of the forest underneath the canopy formed by the crowns of tall trees.

Eventually, the vegetation will recover from the clearing or disturbance, and revert to its original state. This process is known as 'succession', so-called because different types of plants succeed each other as conditions change. Corlett[18] described four stages of succession on degraded land in Singapore:

1. Recently cleared and abandoned land is invaded by herbaceous and smaller woody pioneers and there is no distinct foliage canopy.

2. The woody pioneers form a canopy over the ground, and eventually shade out the herbaceous pioneers, which need plenty of light for full growth.

3. A transition occurs and the pioneers are slowly replaced by a different set of species.

4. Tall secondary forest.

Previously, a distinction was made between the low and tall secondary forests, the former being shorter than 10 metres, and the latter being taller[25]. However, this separation is quite arbitrary. Stages 1 and 2 correspond to the old concepts of belukar muda ('young secondary forest' in Malay) and belukar tua ('old secondary forest'). At present, Kent Ridge seems to be at stage 2 of Corlett's model, as it is still dominated by the original species of pioneers.

The 'original state', or 'climax' that the Ridge belukar should revert to is the lowland tropical dipterocarp rainforest[70]. However, this will take an extremely long time to happen, as dipterocarps (as mentioned above) are very poorly dispersed. The seeds, although winged, can only fly up to a maximum of 100 metres (100 yards) in a very strong wind, and according to Ridley[45], dipterocarps take about 30 years to reach maturity and start fruiting, hence in the most ideal case, they would take 58666 years to cover 100 miles of land, and this is discounting other threats to dipterocarp survival, e.g. the need to be tall to catch drafts of fast wind, and the possibility of the seeds being consumed by rodents and other animals.

In order for the belukar to proceed beyond stage 2, new species of plants from the older forest need to recolonize the land. However, Kent Ridge is in the middle of the urban jungle, and the only sources of seed for these plants are several kilometers away in Bukit Timah and the Central Catchment area. Bukit Timah is the only primary forest in Singapore, and the Central Catchment is the most mature secondary forest[18]. Hence, in this state of isolation, the future of Ridge vegetation is uncertain. Recently, however, dipterocarp seedlings have been planted at various sites in Kent Ridge Park, to begin a process of human-aided succession. Hopefully, they will thrive and form the beginning of another phase in the life of Kent Ridge's belukar forest, but any results are still decades away.

4 Land Use History

Adinandra belukar occurs on land that has been degraded by agriculture and development, then subsequently abandoned. It reflects the common pattern of historical land use in Singapore over the years. The land of the Ridge has seen various types of uses.

Prior to 1845, the area was probably covered by undisturbed lowland rainforest that now can only be seen in Bukit Timah.

From about 1845 to 1945, the Ridge was covered by settlements and was used for rubber plantations. Some rubber trees still persist on the Ridge, and Holttum[26] reports seeing old and dying rubber trees along the Gap, where Buona Vista Road cuts through the Ridge.

From 1945-1959, the plantations were largely abandoned, being unproductive after having exhausted the soil of its nutrients, and the primary land use was residential and military.

From 1959-1970, the area used for residential purposes increased, and from 1970 to the present, the Ridge is largely known for housing the National University of Singapore campus.

In addition, associated with the settlements and kampungs on the ridge were small-scale agricultural holdings, planting vegetables and fruits, such as tapioca (*Manihot esculenta*), sugarcane (*Saccharum officinarium*), and banana (*Musa paradisica*). Some of these cultivated plants have escaped into the Ridge vegetation. Horticultural plants like the Money Plant (*Epipremum bipinnatum*) also grow wild on the Ridge. Settlers in the past also collected firewood from the Ridge, but these settlements have long been cleared and their residents re-settled.

5 Soil Erosion

The intensive land use on the Ridge has resulted in very deep erosion and weathering of its soil by 12 to 25 metres. The evidence for the deep erosion of the soil are the numerous boulders that can be seen in several places along Kent Ridge Road. Because of erosion, the humus (organic matter) content of the soil is low, and the soil's nature strongly reflects the characteristics of the rocks that lie underneath. The rocks on Kent Ridge are from three formations: the Kallang, Tekong, and Jurong formations[43]. These are mostly sandstone and mudstone formations, and so the soils they form are mostly sediment, deficient in many plant nutrients.

The soil is known to be deficient in potassium (K) and calcium (Ca)[34], hence Ridge plants have to be well adapted to grow under such conditions. While there is leaf litter present, the humus layer is much thinner compared to primary forest, and even more so in areas covered by grass. Organic matter on the ground acts as a 'sponge' to absorb water when the rain comes[26], so without it, the water holding capacity of the soil is reduced. Kent Ridge soil exhibits high surface runoff and a compact nature[50][38]. Water is not absorbed and retained well by the soil, but flows off easily.

The soil is also poorly aerated. Together with the higher soil temperature, due to the greater amount of light reaching the ground compared to primary forests, the environment is drier than primary forest, hence pioneer belukar

plants have to be adapted to lower water availability. Ironically, while the open nature of the canopy causes higher rainfall penetration to the ground, this also results in erosion of the soil that eventually causes the water deficiency.

The high acidity of belukar soil can decrease the solubility and hence availability of macronutrients, especially nitrogen and phosphorus, while at the same time increasing the solubility of toxic substances like aluminium. Therefore, only plants that can tolerate this can survive. The lack of legumes (members of the family Leguminosae), except for the exotic *Acacia*, means that they cannot carry out their nitrogen fixing function for the soil.

6 Exotics

There are many exotic plants that have invaded the Ridge belukar. Many of these are pan-tropical weeds of the Sunflower family (Compositae), as well as alien grasses and sedges that have been introduced. This might be because Kent Ridge is enveloped in an urban area. Since Singapore was, and still is, a busy trading port, many exotic plants have followed traders in from overseas.

Woody alien plants are also present. The most prominent of these, and also the most successful, is *Acacia auriculiformis*, the Wattle, which is a native of northern Australia, the Torres Straits, and southern Papua New Guinea. It was brought to this region as a horticultural plant and also as a source of timber, and Nicholson[39] calls it "...a very useful tree, especially for replanting waste areas...." Hill[25] notes that it was purposely planted in Kent Ridge along the Gap. The tree was also used as a wayside tree by the government before it was abandoned due to its excessively vigorous growth and rapid dispersal. Other trees along Kent Ridge Road are also possibly planted as wayside trees, for example *Adenanthera pavonina*, the Saga tree, as well as *Causuarina equisetifolia*, which is found naturally on sandy shores. But *Acacia* is still the most common exotic, and this is due to several factors:

1. It is well suited to the dry and exposed environment of the belukar, and also has tough 'leaves' like native belukar plants.

2. Its growth is fast, and it matures rapidly, competing with the natives for light and nutrients.

3. Being a legume, its associated root nodules can fix nitrogen and give it an edge in growth.

4. Its brightly coloured yellow aril attracts birds which feed on its numerous seeds that are produced year round and hence disperse the plant.

So even though it is an exotic that has evolved in another region, it shares many characteristics and adaptations with belukar plants and so is able to compete favourably with them.

As mentioned above, horticultural plants and food plants have 'escaped' from peoples' gardens to grow wild on the Ridge. It was quite surprising for me to stumble upon a patch of *Sanseviera* sp. growing wild in the shade of the belukar trees. *Epipremnum*, the money plant, can also be seen climbing up trees together with the native *Smilax* spp. These weeds may compete with the native plants and smother them out, or compete with them for nutrients, and

hence reduce plant diversity. Veldkamp[64] complained about how tropical flora is becoming increasingly homogenized, and in the belukar, where plant diversity is already much less than primary forest, the threat of exotics is great. On the other hand, the exotics are established mostly at the edge of the forest, where (i) human disturbance is the greatest and most continuous, and (ii) the conditions are the best for their growth. Even plants as successful as Acacia have not yet penetrated to the core of the belukar forest, though in time they may.

Other foreign invaders include *Mimosa pudica*, the sensitive plant, and *Lantana camara*, one of the top ten weeds worldwide. With the increased exposure of the Ridge to external influences and urbanization, the belukar will be increasingly infiltrated by plants that 'should not be there'. Presently, the belukar natives are holding out, but the future is uncertain. According to Muladiar[38], two-thirds of belukar plant species are natives. While this statistic compares favourably with other forms of land use, e.g. urban green space and residential, it is still much less than primary forests.

7 Plant-Animal Interactions

Plants and animals interact in many ways, both mutually beneficial and antagonistic. The most important ways they can help each other are dispersal and pollination. Many examples can be found in Ridley[45].

7.1 Dispersal

Dispersal is important for the pioneer belukar plants to be widely distributed and more successful in the secondary forests. Most belukar plants are dispersed by animals, especially birds and bats, which are highly mobile creatures. Many of the plants have edible fruits, which are consumed by the animals and then spread over a wide range when the animals expel the seeds in their faeces. Belukar plants tend to flower and fruit at a young age, and each fruit tends to have many seeds. For example, Chin[15] reports that *Melastoma* has between 394-1472 seeds per fruit, while *Adinandra* has between 83-189. The seeds are also very light and small, e.g. *Adinandra* seeds are an average of 0.948 mg, and those of *Fagraea* average 0.269 mg. All these factors contribute to their ease of dispersal. Compared to the dipterocarps, they make use of the mobility of animals to help them in dispersal. Hence, they can colonize newly abandoned land vigourously. In fact, seeds of *Melastoma* germinate better after passing through the digestive tract of a bird[15], so animals are more than just simple carriers for the seeds.

Phua and Corlett[42] report that the Lesser Short-nosed Fruit Bat, *Cynopterus brachyotis*, consumes a wide variety of fruits, including a significant number of the belukar plants, like *Adinandra*, *Fagraea*, and *Vitex pinnata*. *Cynopterus* tends to fly to the fruits, bite them from the tree, then fly away to another place to consume the flesh of the fruit and drop the seeds before flying back for more. Because of this behavior of the bat, the seeds are dispersed over a wider area than they would if the bats simply stay in place to consume the fruits.

Birds also feed on a wide variety of fruits. The Yellow Vented Bulbul feeds on *Rhodamnia*, *Melastoma*, and *Cinnamomum*, while the Turtle Dove feeds on *Melastoma*, which Ridley[45] said was "one of the first bushes to appear in the

waste fields of lalang grass, where the seeds are dropped by pigeons and bulbuls." Bulbuls also tend to go after the seeds of *Dillenia*, perhaps being attracted by the bright red colour of the arils. The successful alien plant, *Acacia auriculiformis*, is also dispersed by birds, which are attracted to its seeds by the bright yellow arils.

In more mature secondary forests, monkeys are active dispersal agents, 'attacking vigorously' the fruits of *Eugenia*, *Passiflora*, etc. However, they are not commonly encountered on the Ridge, though a number were sighted a few years back and may or may not still be present. Finally, there is the interesting case of *Ploiarium alternifolium*, another pioneer plant, where the seed capsules dehisce (split) on the plant, and rain washes them down to be dispersed.

7.2 Pollination

Pollination is carried out by many insects. Turner notes that carpenter bees (*Xylocopa latipes*) can be seen pollinating *Dillenia* and *Melastoma* in Singapore. In addition, the figs, *Ficus* spp. are famously pollinated by the tiny fig wasps, which lay their eggs inside the figs. The eggs then hatch and the wasps mate. The males die and the females squeeze out of the fig to lay their eggs, and in the process pick up pollen. When they enter other figs to lay their eggs, they deposit the pollen and hence pollinate the figs.

7.3 Myrmecophytes

Macaranga triloba, the Mahang, is a plant that can be found in *Adinandra* belukar though more commonly in *Trema* belukar. It is a myrmecophyte, which literally means 'ant plant'. Its stem is hollow, as the pith within disintegrates just behind the growing tip. Within the hollow, ants of the species *Crematogaster borneensis* establish their colonies. Small holes along the stem can be seen where the ants enter and exit. The plant also provides small white food bodies for the ants to feed on. In return, the ants protect the plant against foreign invading insects and other small creatures. The ants also bite off the growing tips of plants that come near the *Macaranga* plant, hence preventing vines and other plants from growing over and smothering it.

8 Adaptations

8.1 Strategists

Ecologists have grouped the life cycles of plants into two categories, based on strategies they use to adapt to the need to reproduce and disperse. The so called r-strategists are herbs that are short lived, light demanding, and expends most of its effort to produce large amounts of seeds. On the other hand, K-strategists are slow growing long-lived trees that expend resources to produce a large stature, have shade tolerant seedlings, and have larger, fewer and poorly dispersed seeds. The former is adapted to rapidly changing environments, being able to quickly grow and disperse its seeds so that at least some may survive to continue the lineage, while the latter is adapted to stable, unchanging environments. As can be seen, belukar plants tend to be r-strategists. They are adapted in many ways

to survive and be more successful in the belukar environment and the challenges they have to contend with.

8.2 Water

To deal with the low amounts of water available to them, belukar plants have thick and small leaves[60], with more dry weight per unit area than primary rainforest plants, which, according to Whitmore[70], tend to have large and thin leaf blades. Furthermore, *Adinandra* belukar plants have tough and sclerophyllous leaves in comparison with Trema belukar plants[8], most likely since the latter have more water available to them in a more humid environment. According to Chee[13], rhizosclereids can be found in *Adinandra*, and astrosclereids in *Fagraea*. Sclereids are modified cells in leaves that cause them to be tough (and are responsible for the stony texture of pears). He also reports the texture of most belukar plants as coriaceous or chartaceous, qualitatively confirming the tough nature of the leaves. Having tough leaves may also be a form of protection against animals consuming the foliage, as they would tend to choose softer and tender leaves for consumption[16].

Pioneer plants tend to have low resistance to water transport[3]. *Adinandra*, *Melastoma*, and *Ploiarium* also have young in-curled leaves, possibly to reduce water loss by transpiration by creating a small zone of more humid air around the leaves. In addition, most important belukar species have about 2 layers of cells in the upper palisade mesophyll layer in their leaves, except for *Vitex* (1 layer) and *Fagraea* (4-5 layers). This is another means of preventing water loss through the leaves. *Dicranopteris*, the sun loving fern, has a waxy cuticle layer on both sides of its fronds, as well has a closely arranged palisade mesophyll layer – both are tactics to avoid water loss. In addition, the stomata in *Dicranopteris* fronds are sunken and surrounded by raised cells, which create pockets of humid air around stomata to reduce water loss. The waxy cuticle on the underside of *Dicranopteris* is flaky, and hence may act as 'heat fins' to dissipate excess heat as the plant is often in direct sunlight[49].

8.3 Growth and Photosynthesis

In order to have successful establishment and dispersal, belukar plants mature very fast. For example, 6 day old *Adinandra* and *Fagraea* plants already have primary roots covered in root hairs. *Macaranga* spp., another common pioneer plant, produces lateral roots when only 1-4 days old[15]. Fast root growth is important to get water, since lack of water affects young seedlings more than mature plants.

Belukar seedlings are also light demanding, needing a lot of light for good growth. This gives them an advantage over the shade-loving forest-floor herbs found in the understorey of primary forests. Their rapid growth results in tall and thin mature trees, almost like poles. Venturing into a belukar forest is like walking into a forest of poles. Belukar plants have high photosynthetic rates, and high light saturation intensities. Their maximum photosynthetic rates are higher than primary forest plants. Hence, they can better cope with the greater light exposure in belukar, and the high rate of photosynthesis means that the plant can generate more biomass quickly and grow rapidly. Turner et al[62] report that primary forest herbs are rarely found in mature secondary forest

in the Central Catchment area where they might disperse to, perhaps because they do not favour such environments which belukar plants prefer. However, the photosynthetic apparatus of belukar plants is not very efficient, and Boo[8] suggests that this might be due to insufficient nutrients being channeled to it. Interestingly, a light-demanding plant like *Dicranopteris* may end up having too much light as it tends to grow in exposed places, hence to cope with that problem it has undulations on the surface of its fronds that reflect off some of the incident light, reducing light intensity and the possibility of light damage to plant cells[49].

8.4 Nutrition

Nutritionally, the soils are deficient. Therefore, the plants which grow in belukar need to survive on low nutrient concentrations. In fact, high nutrient concentration may even be toxic to belukar plants. *Nepenthes* spp. attempt to supplement the little nitrogen they can get from the soil by having insect-capturing pitchers, which are mentioned above. They digest insects and even small animals like tapdoles (although some creatures can survive in the pitchers) for their protein, which is a source of nitrogen. Their presence in belukar is a very good indicator of the nutrient poverty of the soil. Although legumes (except for the exotic *Acacia*) are not commonly found in belukar, *Myrica esculenta*, a common plant on the Ridge, forms an association with *Frankia* (an actinomycete fungus) that forms root nodules that fix nitrogen[50].

9 The Future

Kent Ridge is being increasingly developed. The patches of forest remaining are being isolated and surrounded by developments, e.g. housing and and university buildings newly built along the Ridge. The Ridge is treated as wasteland or a free 'dumping ground' by some building contractors, and piles of building refuse can be seen along the road. Kent Ridge is highly isolated from other natural areas, and its increased fragmentation will lead to the 'edge effect', where the ratio of forest boundary to forest area is high, causing external influences acting on the Ridge forest from the outside in to have greater effects. Drying winds blowing through the forest reduce its humidity, and rainfall coming in washes away humus. Hence, the forest is effectively being prevented from carrying out its natural maintenance. The soil and the flora of the Ridge may end up being permanently poor, with the situation made worse by its distance from sources of seed for the further stages of succession to proceed. Buildings and other structures also store up heat during the day and release it during the night, hence radiating heat into the forest due to its close proximity. This affects both the plant growth and animal life.

Transects of the Ridge[38] have shown interesting results. Land on the Ridge is mostly urban, belukar, or abandoned open land. *Acacia* can be found in belukar and abandoned areas. Plants like *Cinnamomum iners* have escaped to abandoned land too. However, most trees found within belukar are restricted to it, especially natives and notably Adinandra itself. They have not escaped to abandoned open land. Some plants that are not conventional belukar plants, like *Durio zibethinus* (Durian), *Pterocarpus indicus* (Angsana) and *Tabebuia*

sp. (Tabebuia, an ornamental) are present in these open spaces. The first is probably from settlements and villages, the second was planted as a wayside tree by the government, and the last can be found in some private gardens on the Ridge. Other non-belukar plants that can be found there are *Millettia artopurpurea*, *Cassia* spp., and *Areca catechu*. From the trends, it seems that most of the belukar 'invaders' are from one of three sources: (i) cultivated as food in former kampungs, (ii) planted as wayside trees by the government, or (iii) horticultural shrubs from private gardens. Not many belukar plants are successful in colonizing land outside the belukar, perhaps because the conditions are different than from the original disturbances in which they first established themselves about 50 years ago. In particular, *Nepenthes* is not commonly seen outside the belukar. A possible reason is that its pitchers are in demand by collectors and passers-by, making them a rare sight in places with high human traffic.

Despite of the invasion of the Ridge by alien plants and poor original plant diversity (compared to primary forests), the belukar is still 'natural' and has a function to play. Within the forest, away from the bustle of the urban areas, many species of birds and animals still survive in the heart of the city. Many species of insects and invertebrates are also present, and require the leaf litter and shaded conditions of the forest to survive. The birds and bats feed on the fruits of the belukar plants, and we humans can think of this favourably, as we would prefer them to feed in the forest than loiter in our food centers and canteens. Still, the Ridge forest should be preserved for its own sake. Encouraging people to recreate on the Ridge, which is more convenient to access than our other forested areas, will give them a better appreciation of the nature that can be found close to their homes.

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