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RESEARCH NOTE

Virtual gallery of the vegetation and flora of the Seychellles

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Summary

1 The Seychelles archipelago has been identified as a biodiversity hotspot by international conservation agencies. One of the major threats to the Seychelles native species and forests is the rampant spread of a large number of invasive alien plant species. As a basis and reference for conservation measures, the native flora and some vegetation types of granite islands of the Seychelles are briefly described and illustrated with photographs.

2 The original flora of the granite islands was rather poor with approximately 250 species of indigenous flowering plants of which about 34% (84 taxa) are supposed to be or to have been endemic to the Seychelles. About 80 fern species grow on the islands, several of which are considered endemic.

3 The main natural vegetation types are: coastal plateau, lowland and coastal forests, mangrove forest, riverine forest, intermediate forest, mountain mist forest, glacis type vegetation (inselbergs)

4 A collection of photographs of plant species and vegetation types from the Seychelles ('virtual gallery' can be viewed or downloaded at www.geobot.umnw.ethz.ch/publications/periodicals/bulletin.html

Keywords: conservation, endemism, island flora, plant invasion, Seychelles, vegetation types.
Nomenclature: Friedmann (1994).

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Introduction

The Seychelles archipelago consists of about a hundred granite and coralline islands near the equator in the Western Indian Ocean (Fleischmann *et al.* 1996). These islands probably split from Gondwana some 65 million years ago and have been isolated from continents ever since. The Seychelles flora therefore had an extremely long time to develop independently from that of the rest of the world, mainly through natural evolutionary processes, leading to a high level of endemism. The unique status of the granite islands of the Seychelles as oceanic islands of continental origin, and the phytogeographical im-

portance of the islands as combining African, Madagascan and Indo-Malaysian elements in their flora make it a region of great floristic interest. The fact that at the time of the first human settlement on Mahé in the 1770's the flora had evolved continuously and without human interaction for many millions of years, certainly adds to the outstanding status of the Seychelles' island vegetation. In fact the Seychelles have been identified as a biodiversity hotspot by Conservation International and as a centre of plant diversity by the WWF and IUCN.

One of the major threats to the native species and forests of the Seychelles is the rampant spread of a number of alien plant species across the islands (Fleischmann 1997); the most invasive ones are *Cinnamomum verum, Psidium cattleianum, Clidemia hirta, Merremia peltata* and *Paraserianthes falcataria.* These plants displace the distinctive native flora of the Seychelles, resulting in the loss of diverse native forests. The situation in the Seychelles is particularly serious because there are several rare, endemic species like *Medusagyne oppositifolia, Secamone schimperiana, Vateriopsis seychellarum* etc. which are fated to extinction following the invasion of a great variety of introduced organisms. It is generally accepted that invasive alien species may have a competitive or reproductive advantage over native species (Parendes 2000). Besides this, the introduction of certain plant species may promote further change because they affect ecosystem processes. Invasive species can influence nitrogen availability by changing litter quantity and quality, rates of N_2-fixation, or rates of nitrogen loss (Evans *et al.* 2001; Anderegg & Wiederkehr 2001). A variety of biological attributes of plants serve to make them invasive, but in the Seychelles three are of primary importance.

- Propagules dispersed by animals. Animal-dispersed seeds are typically fleshy berries, relatively small in size, and variously colored. The dispersers of greatest importance in the Seychelles are fruit-eating birds and bats. Prominent amongst introduced species with bird-dispersed fruits are *Cinnamomum verum, Psidium cattleianum* and *Clidemia hirta.* Species using animals or wind as dispersal mechanisms (i.e. *Paraserianthes f.*) are capable of quickly invading native ecosystems in areas remote from where the adults themselves are planted. As for *Cinnamomum v.* and *Psidium c.* an additional attribute making these plants even worse is that they can reproduce vegetatively as well as by seeds.
- High fecundity. Species that produce many seeds per plant each year can invade new habitat patches more rapidly than can most native plants that produce relatively few seeds (Peters 2001). For example, *Cinnamomum v.* and *Clidemia h.* (the latter is now the subject of a control effort by state and private organizations) produce large numbers of seeds, so that their populations can increase very rapidly, which partially accounts for the great threat they pose to the Seychelles' forests.
- Fast growth: Fast-growing plants that quickly reach maturity will be more invasive and harder to control than slower-growing plants. An outstanding example of the importance of this phenomenon is *Clidemia h.* which was first seen on Mahé island in 1993 (Gerlach 1993). Since then single plants have been found all over the island. By competing with native species in gaps, *Clidemia h.* invasion has the potential to alter forest regeneration (Peters 2001).

In order to prevent fundamental changes to the indigenous and endemic vegetation of the

Seychelles an ongoing commitment to controlling invasive alien species is required. This commitment is based on scientific research which provides a wider perspective on the problem of invasion by alien species, and a rational basis for habitat management (i.e. the control of this invasion). It has become obvious that the protection of land in itself will not be sufficient to save the habitats. Since most areas of the Seychelles are heavily infested with alien plants, the crucial question is: what can be done to save the remaining, intact native forests? To address this question, several research projects in the field of conservation and invasion biology have been conducted through the Geobotanical Institute in Zürich over the last eleven years.

Despite the wide scale destruction of the original island vegetation, there are sites where at least some of the original elements of the natural flora have been preserved. On Mahé and Silhouette there are still substantial areas of humid high-altitude forests and inselbergs containing a rich endemic flora. Luckily, relatively few of the endemic plant species are so far known to have become extinct on all islands (Carlstroem 1996). However, the fact that populations of many endemic and threatened species are extremely small is a serious concern. For many of these species, especially those of the ancient forests at intermediate altitude, the situation is critical since their natural habitats no longer exist. These species (e.g. *Medusagyne oppositifolia*) will never survive without human interference. It is most likely that the displacement of the native flora through competition with invasive exotic taxa will reduce biodiversity through the altering of the physical environment, increased erosion and perhaps the disruptive effects on nutrient recycling.

Given the critical status of the last remnants of native Seychelles vegetation, it is essential to carefully describe and document their present condition as a reference for future conservation measures. The purpose of this article is (a) to give a brief account of the historic development of the Seychelles flora and (b) to describe its main vegetation types with characteristic plant species. This description is illustrated by photographs available in electronic form. A similar account was given by Francis Friedmann (1987) in his book "Flowers and Trees of the Seychelles". This book comprises a selection of remarkable pictures of the Seychelles flora on the granite islands, including typical habitats and beautiful scenes. Unfortunately, this work is now out of print and cannot be re-printed in the original form because many of the original pictures were destroyed by fire. Therefore, this contribution and the associated "virtual gallery" with photographs of prominent plants and typical vegetation types is intended to be a small substitute of what is no longer available.

The Seychelles flora and its history

Thanks to a large number of contributors and the rather restricted area of the land, the flora of the Seychelles is at present rather well known and we have a fairly good knowledge of the conservation status of most species. The original flora of the granite islands was rather poor with approximately 250 species of indigenous flowering plants of which about 34% (84 taxa) are supposed to have been endemic. There are also about 80 fern species growing on the islands, several of which are supposed to be endemic to the Seychelles (Fleischmann 1997).

While most oceanic islands have received their flora predominantly by long-distance (i.e. 1000 km) dispersal, the native flora of the Seychelles probably derived predominantly from ancestors which were already present

on the Seychelles microcontinent 65 million years ago when the archipelago was about to split up from Gondwanaland. Few species in the Seychelles have seeds that are adapted to long-distance dispersal. Before the arrival of humans, only a minor part of the native flora, mainly in the coastal zone and in the wetlands, had probably arrived by long-distance dispersal.

As can be expected from the geological history of the area, the native flora of the Seychelles includes elements of African, Madagascan and Indo-Malaysian origin, with the latter being the most prominent (Cox & Moor 1996). A considerable proportion of the endemic species are probably relict elements from an ancient widespread Gondwana-flora which became extinct on the mainlands but survived in the Seychelles. Many primitive characters have been preserved in relict species such as *Medusagyne oppositifolia* and *Psathura seychellarum* (Procter 1974).

After the ice age a period of submergence followed when the Seychelles microcontinent was reduced from a more or less continuous land mass of 43'000 km^2 to scattered islands with a total area of about 245 km^2 (Stoddart 1984). This dramatic reduction in land area undoubtedly must have been accompanied by massive extinctions in the flora. The species occurring in the lowlands would have been especially affected. This theory is supported by the fact that the main part of the endemic species are found at intermediate and high altitudes, whereas only two species are confined to the coastal zone.

During the long period of isolation of the islands, evolution may have slowly given rise to new plant species like *Lodoicea maldivica* (Edwards *et al.* 2002). Groups of taxa which have probably evolved after the isolation of the Seychelles microcontinent exist within genera like *Gastonia* (three species and three varieties), and in the Hypoxidiaceae (*Hypoxidia rhizophylla, Hypoxidia mahensis*) (Carlstroem 1996).

The present flora of the Seychelles is relatively homogeneous (Carlstroem 1996). No differences in morphological characters were observed between populations on different island (Fleischmann, personal observation). However, it is still possible that genetic differentiation exists among the different island populations; this could be revealed by genetic analyses.

Natural vegetation types on the granite islands

Although a full documentation of the original vegetation types of Seychelles is lacking, some conclusions can be drawn from the present vegetation, in combination with old written records. The following vegetation types have been identified on the granite islands.

COASTAL PLATEAU

We only have very scarce reports on the composition of the shore vegetation from the earlier records, which mainly noted the more important timber trees. The exploitation of the trees of the beach crest as well as the construction of sea walls, land reclamation, construction of houses, coconut plantations, etc. have all contributed to the alteration of the original coastal vegetation. Our knowledge about the original composition is therefore limited (Sauer 1967).

By the time the first settlers arrived on the Seychelles the shores were fringed with coconut palms which were believed to have grown from nuts cast up by the sea. Other trees mentioned from the shores in the earlier reports were *Casuarina equisetifolia, Terminalia catappa, Calophyllum inophyllum, Cordia subcor-*

data. It has been much discussed whether *Terminalia catappa, Casuarina equisetifolia* and *Cocos nucifera* were brought to the Seychelles by the first people visiting the islands or whether they were present before the first arrival of humans. Certainly they were already widely spread by this time, and they now form an integral part of the coastal vegetation.

The dominant shrub on the beach crests today is *Scaevola sericea.* Other common shore-line trees are *Cocos nucifera, Calophyllum inophyllum, Hernandia nymphaeifolia, Hibiscus tiliaceus, Barringtonia asiatica, Guettarda speciosa* and *Cordia subcordata,* in the past frequently mixed with *Tournefortia argentea, Suriana maritima* and *Sophora tomentosa.* Scramblers and creeping plants are common in the shore vegetation. Most species growing along the coast are species common to the shores of most tropical islands and the endemic flora has never played an important role on the littoral.

LOWLAND AND COASTAL FORESTS

The lowland forests originally covered the mountain sides up to about 200–300 m. The coastal plains were originally described as being covered by magnificent trees reaching up to 20–25 m, with a circumference of 4–5 m and with very straight trunks. The trees were spaced at 2.5–3.5 m from each other with hardly any branches for the first 15–20 m. Species like *Terminalia catappa, Casuarina equisetifolia, Intsia bijuga, Calophyllum inophyllum, Heritiera littoralis, Mimusops seychellarum, Vateriopsis seychellarum, Syzygium wrightii* and *Cordia subcordata* were described as common in this zone in the first records. Palm trees, especially *Phoenicophorium borsigianum, Nephrosperma vanhoutteana* and *Deckenia nobilis* were also mentioned from the original lowland forests, especially on dry ridges. The species composition of the woods of Silhouette was described as being the same but smaller. The islands of Cousin, Cousine and Aride were apparently never well wooded and were described as covered by scrubland even in the first records from Malavoise 1786–87 (Carlstroem 1996).

The primary lowland flora was apparently composed partly of endemic species as well as indigenous species more widely spread on most islands in the Indian Ocean; however, it is obvious that the endemic species played a less important role in the lowland vegetation than at the higher elevations.

MANGROVE FOREST

Near the sea level were also the mangrove swamps dominated by the same six species of mangrove trees that occur today, with *Avicennia marina* and *Rhizophora mucronata* being the most prominent at present. The exposed open sea coasts have never been colonised by mangroves. Hence the mangrove have always been found only on the more tranquil lagoon shores. The earliest settlers reported extensive areas covered with almost impenetrable mangroves, especially along the East coast of Mahé. All species known from the mangrove swamps have a wide distribution and no endemic species are known to occur in this vegetation type.

RIVERINE FOREST

The vegetation along most rivers in the Seychelles was much affected by human activities and there is little information on riverine forests to be found in the literature. Most of the remaining river forests are composed of palm trees, especially *Phoenicophorium borsigianum, Verschaffeltia splendida,* frequently associated with *Barringtonia racemosa* and *Pandanus balfouri* at the lower altitudes. Possibly *Vateriopsis seychellarum* also formed part of this community. There also seems to be a constant asso-

ciation of *Pandanus hornei* and *Verschaffeltia splendida.*

INTERMEDIATE FOREST

From 200 to 500 m there was an intermediate forest zone. These forests were rich in species and had a high canopy at least occasionally reaching up to 30–40 m. The big trees were spaced at approximately 9–10-m intervals, and the trunks were very straight. The forest at intermediate altitudes was the one richest in endemic species; endemics made up the main part of the vegetation. These forests have now been almost entirely cut down and most of the remaining areas have been heavily invaded by exotic species or have been planted with exotic forest trees. Areas with intermediate forests with at least remnants of the high canopy are now very rare in the Seychelles. Most of the remaining forests have been combed through for timber and most suitable tall trees have been cut down. It is therefore difficult to judge what the species composition in these forests was like and evidence of its former appearance can only be gained from much modified scattered patches. Our best knowledge of the vegetation from the intermediate altitudes comes from the exposed rocky areas and some river ravines which have served as sanctuaries for much of the flora.

At drier sites the intermediate forests have probably been dominated by the endemic palm trees associated with *Campnosperma seychellarum, Diospyros seychellarum, Memecylon eleagni, Excoecaria benthamiana, Paragenipa wrightii, Erythroxylon seychellarum, Syzygium wrightii, Canthium bibracteatum, Soulamea terminalioides,* etc., whereas forests at more humid sites were dominated by *Northea hornei, Dillenia ferruginea, Vateriopsis seychellarum, Grisollea thomassetii, Pouteria obovata, Campnosperma seychellarum,* and *Gastonia crassa* (Bwa Bannann). Palms were of only minor importance in the forests of the more humid type. There were also large stands of screwpines (Pandanaceae). Tree ferns (*Cyathea seychellarum*) have been described as a common feature in the humid intermediate forests and along the river ravines. Much of the dry ridges with a shallow soil have been described as having a *Mimusops / Excoecaria* dominated forest type. This kind of vegetation is now only to be found as scattered remnants on rocky outcrops. The creeper *Merremia peltata* and the only recently established *Clidemia hirta* have started to heavily invade the lowland- and intermediate forests on Mahé.

MOUNTAIN MIST FOREST

High altitude forest originally covered most land above 400–500 m in the Seychelles. On mainland tropical mountains, mist forest is typically found at altitudes of between 2000 and 3500 m, but on steep small islands like the Seychelles mist forests develop at much lower altitudes. The transition into the mist forest zone is gradual and depends greatly on local conditions. In many places the transition between the intermediate and high altitude forests have been obscured by the dominance of exotic vegetation, which grows from sea level to the highest elevations, making the transition less obvious. The conditions at the high altitudes are more humid and a mountain mist forest develops where the annual rainfall is well over 3000 cm yr^{-1}. These areas are often enshrouded in low clouds.

Even these high altitude areas have suffered from heavy cutting of selected trees, so there are only a few relict stands of primeval forest left. The remaining areas, however, give us an idea of its former appearance. The remnants of high altitude forest are still dominated by native species, giving an idea of the original

structure of this forest type. The mountain mist forest is rich in mosses, lichens, filmy ferns and epiphytic orchids. Tree ferns (*Cyathea seychellarum*) are a common feature of this forest type. Climbers like *Schefflera procumbens* were described as a characteristic feature in the past but are now much less common. The trees in the mist forest exhibit a reduced tree stature and increased stem density compared to forests of lower lying areas.

As a result of the cutting of the best timber trees in the canopy, the second-story trees often form a new lower canopy today which is lower than the original. However, big trees can still be found at undisturbed sites at higher altitudes indicating that the canopy was previously up to about 15 m tall with a circumference of more than 2 m. *Northea hornei* was, and still is, the dominant species of the canopy of this zone. It commonly occurs with *Pandanus seychellarum* and with a second-story vegetation of *Roscheria melanochaetes, Gastonia crassa, Psychiotria pervillei,* etc. In the original forest at the higher altitudes endemic species dominated the vegetation. The total number of endemic species in the mist forest is, however, lower than at the intermediate altitudes.

GLACIS TYPE VEGETATION (INSELBERGS)

On the granite islands of the Seychelles there is a vegetation element which cannot be related to altitude. This vegetation type, comprising vegetation growing on solitary, often monolithic rocks or parts of mountain systems which rise abruptly from their surroundings, is locally called "glacis-type" vegetation. The term "glacis" is French and means "steep, rocky slope". Glacis are freely exposed precambrian rock outcrops, which in geomorphological terms are known as inselbergs. On the Seychelles they occur throughout the above-mentioned habitats from the seashore to the mountain tops. Extreme edaphic and climatic conditions (high degree of insolation combined with high evaporation rates) exert an strong selective pressure resulting in a vegetation that is very different from the surroundings. Soil which accumulates in pockets and fissures of the rock consists largely of coarse quartz sand with variable amounts of peaty organic matter. If the peat cover is destroyed by clearing of the vegetation or fire the underlying bare rock is exposed. These factors have given rise to a vegetation type which is characterised by an outstanding degree of endemism, locally as high as 96%. Taxa typically growing on inselbergs are *Pandanus multispicatus, Memecylon eleagni, Mimusops seychellarum, Excoecaria benthamiana, Soulamea terminalioides* and on just a few locations the very rare *Medusagyne oppositifolia.*

Virtual gallery

A collection of photographs of typical vegetation types and their characteristic plant species is given under http://www.geobot.umnw.ethz.ch/publications/periodicals/bulletin.html (on this web page, select "Electronic Appendices", and there "App. 2003-7").

This Appendix consists of a text part, which provides a concise compendium of the most important vegetation types, and a total of 74 photographs, which can be accessed from the text through hyperlinks. Most plant species mentioned in the two preceding sections of this article are represented in the virtual gallery. The photographs can be viewed on the screen and downloaded as jpg files. They have been produced by Karl Fleischmann, Pauline Héritier and Cyrill Meuwly during field work in 2001–2002. They can be used freely for teaching and scientific purposes, provided that the full source is indicated.

It is the authors' hope that a wider appreciation of the beauty and uniqueness of the Seychelles flora, as reflected by the photographs in the virtual gallery, will stimulate further research aimed at protecting these plants against increasing human disturbance and alien plant invasions.

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Electronic Appendix

Appendix 1. Typical vegetation types of the Seychelles (classified according to altitude) and their characteristic plant species, with hyperlinks to colour photographs.

The Appendix can be downloaded at
http://www.geobot.umnw.ethz.ch/publications/periodicals/bulletin.html
(select 'Electronic Appendices', App. 2003–7).