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Case Studies on the Status of Invasive Woody Plant Species in the Western Indian Ocean

5. Seychelles

By

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For detailed studies on individual countries and territories, please refer to:

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1. GENERAL BACKGROUND

Seychelles consists of a scattered group of 115 granitic and coralline islands in the Western Indian Ocean with a total land area of 438 km^2 (Stoddart 1984a).

The granitic islands cover 53 percent of the total land area (INDUFOR 1993) and include Mahé, Praslin, Silhouette and La Digue. Mahé is the largest island with an area of 154 km^2 or 32 percent of the total land area, rising to 914 m asl (above sea level) at its highest point (Morne Seychellois) (Stoddart 1984a). The coralline islands, in contrast, rise only a few metres above sea level.

The climate is equatorial with an average rainfall of 2 200 mm. Humidity is uniformly high, and mean temperatures at sea level range from 24°C to 30°C (Walsh 1984). The prevailing winds bring the wet northwest monsoon from December to March and the drier southeast monsoon from May to October. Climatic conditions, however, vary dramatically between islands, mainly in relation to their altitudes and positions; the mean annual rainfall in the Indian Ocean diminishes from the northeastern to the southwestern islands of the archipelago. Rainfall can be as high as 5 000 mm per year on the top of Morne Seychellois and as low as 867 mm on Assumption (Walsh 1984).

Seychelles has been permanently inhabited by humans since 1770. In 2002 the population amounted to some 81 200 inhabitants, with 99 percent of the population living on the islands of Mahé, Praslin and La Digue. A population of about 100 000 inhabitants is projected in 2016 (Seychelles Management and Information Systems Division 2002).

1.1. A biodiversity hotspot

The vegetation of Seychelles is extremely valuable from the conservation perspective because of its high endemism (35 percent of species are endemic, with 12 endemic genera and one endemic family) (Strahm 1994) but also because of its unique composition. The flora has affinities with that of Madagascar, the Mascarenes (Mauritius, Réunion and Rodrigues) and Asia, even though Asia is twice as far away as Africa.

The endemic species associations are relict and are a direct consequence of the geological history of the country's granitic islands. They were linked with India until 65 million years ago, having separated with India from Madagascar some 20–30 million years earlier (Briggs 2003). They are unique among the world oceans' islands in their combination of isolation and continental origin (Stoddart 1984a). Compared to oceanic islands of volcanic origin, Seychelles has had a far longer history of vegetation development through natural immigration and evolutionary processes.

Larger, higher and older islands have the most endemic species in their floras. The floras of the granitic islands are more varied than those of the coralline islands. Of the coralline islands, the elevated, usually older, limestone islands (resulting from weathering of corals) are richer than the lower coralline islands in terms of floral biodiversity, and their floras also exhibit affinities with those of the granitic islands (Stoddart 1984a).

Of the some 250 indigenous species in Seychelles, as many as 54 taxa or almost 21 percent of the flora are now considered threatened according to the IUCN (World Conservation Union) classification scheme (Carlstroem 1996).

1.2 A WIDE VARIETY OF HABITATS

1.2.1. Granitic islands

The woody vegetation of Seychelles granitic islands may be classified into seven main habitat types (Vesey-Fitzgerald 1940; Procter 1984; Carlstroem 1996): beach vegetation, mangrove forest, lowland forest, riverine forest, intermediate-altitude forest, mountain cloud forest and glacis (inselberg) vegetation.

Coastal vegetation (up to 100 m asl) has been altered by human settlement activities, especially through mining of sand and construction. The majority of species growing along the coast are common to the shores of most tropical islands and the endemic flora has never played an important role here (Carlstroem 1996).

Mangrove forests were formerly extensive and well developed on the shores of the granitic islands, especially Mahé. The vegetation surviving in the remnants of this habitat is similar to that of the East African mangrove swamps (Sauer 1967).

The lowland forests originally covered the main islands up to about 200 m asl, but have been completely cleared. In its natural state, the coastal plateau was described as being dominated by trees of up to 25 m in height and 4–5 m in circumference, also characterized by straight trunks with few branches for the first 15–20 m. The primary lowland flora was apparently composed partly of endemic species and partly of species widespread on most islands in the Indian Ocean, but the endemic species played a less important role here than at higher elevations (Carlstroem 1996).

The intermediate-altitude forests range from 200 to 500 m asl. In Seychelles, these forests were the richest in terms of endemic taxa (c. 60), compared with the coastal vegetation (c. 30), the lowland forest (c. 35) and the mountain cloud forest (c. 40) (Carlstroem 1996). Natural intermediate-altitude forests have now almost entirely been cut down and most of the remaining areas have been heavily invaded by exotic species.

Inselbergs (‘glacis’ in Créole) are isolated rock outcrops that stand out from surrounding plains. They occur throughout all climatic and vegetational zones and often have extreme environmental conditions (Fleischmann *et al.* 1996). In Seychelles, glacis are still characterized by a high abundance and diversity of endemic species.

Riverine forests were mainly composed of palms (Arecaceae/Palmae) and pandans (or screwpines; *Pandanus* spp.), but they have suffered much from human activities and can now only be found in the upper reaches of river systems (Carlstroem 1996).

The mountain cloud forests originally covered most land above 700 m asl. These forests remain rich in mosses, lichens, ferns and epiphytic orchids. Tropical mountain cloud forests differ from lowland humid forests in structure (low diversity; trees of small stature with small, thick sclerophyllous leaves; epiphytes a high proportion of the biomass) and

functioning (low productivity, low nutrient cycling rates). They capture horizontal precipitation from wind-driven clouds and mist. Soils are wet and frequently waterlogged and are highly organic (Hamilton *et al.* 1995; Bruijnzeel and Veneklaas 1998).

1.2.2. Coralline and limestone islands

Low coralline islands have elevations near current sea level (e.g. Bird, Denis, Farquhar), while elevated limestone islands (e.g. Aldabra, Assumption, Astove, Cosmoledo) are a few metres above present sea level (Stoddart and Fosberg 1984). The coralline islands are exceptionally large compared with the rest of the world's reef islands. Seventeen are greater than 100 ha, seven greater than 300 ha, and three greater than 900 ha, compared with, for instance, islands of the Great Barrier Reef, Australia which vary in area from 0.43 to 147.3 ha (Stoddart and Fosberg 1984). The islands vary greatly in their degree of isolation (Stoddart and Fosberg 1984). Stoddart and Fosberg (1984) proposed a classification of atoll and coralline island vegetation types, in which the primary distinctions for woody plant species are between forest, scrub and scrub-forest, and mangrove swamps.

About one-third of the some 400 plant species fall into one of the following three groups: restricted to the elevated limestone islands, restricted to the low coralline islands, and common to both (Stoddart and Fosberg 1984). On limestone islands, 24 percent of the species are endemic and 58 percent are indigenous. On the coralline islands, there is only one endemic species, and eight percent of the species are indigenous. The third category includes one endemic species, while 37 percent of the species are indigenous (Stoddart and Fosberg 1984).

Original forest is mainly composed of indigenous broadleaved trees such as *Cordia subcordata, Calophyllum inophyllum* and *Guettarda speciosa*. *Cocos nucifera* (coconut) and *Casuarina equisetifolia* forests have often been established and have replaced the natural vegetation in numerous cases. Mangrove forests are found mainly on Aldabra and to a lesser extent on Cosmoledo, and have vegetation similar to that of the granitic mangroves. Scrub vegetation, an important feature of coralline islands, is composed of either mixed stands or, often, monospecific stands of species such as *Scaevola sericea, Tournefortia argentea* and *Suriana maritima* (Stoddart and Fosberg 1984).

The vegetation of raised limestone and coralline islands has been disturbed by human settlement activities, particularly phosphate mining, guano digging and the building of airstrips.

1.2.3. Current status of forests

As a result of successive human activities, the forests of Seychelles are very highly degraded, even though they are considered to cover 90 percent of the total land area. Based on an INDUFOR (1993) study:

- Natural forests no longer exist, except as relict vegetation at the highest altitudes and on glacis.
- Sixty-three percent of the forests are secondary forests, and most of these have been invaded.
- Invaded bush vegetation covers 17 percent of the total forested land, mainly on the granitic islands.

- Plantations amount to 12 percent of the forests. However, only ten percent of these plantations (410 ha) are on granitic islands (and these are mainly of *Swietenia macrophylla*). The rest (90 percent or 4 400 ha) are managed *Casuarina equisetifolia* forests on the outer islands.
- *Cocos nucifera* plantations amount to seven percent of the forests.
- Deforested areas amount to one percent of the total forest cover. These are mainly found on Praslin, where they are the result of forest fires.

Compared with tourism, which generated 40 percent of the GNP (Gross National Product) in 2000 (Anon. 2001), the Seychelles forestry sector accounts only for 0.4 percent of the GNP (INDUFOR 1993). Seychelles has clearly shifted its forest policy from a 'production logic' to a 'maintenance logic' that fits better with the aims of its tourist industry. There are few direct economic impacts from the invasion by woody plant species as forest production is now a sideline activity, while the tourist industry is for the moment more interested in selling the 'greenery' of Seychelles and not the composition of this greenery. In Seychelles, the main concern about invasive species relates to their impact on native biodiversity.

2. INVASIVENESS AND DEGREE OF INVASION

In this section, the invasion history, the invasiveness of exotic woody plant species in Seychelles, the main invasive non-woody plant species, and the degree of invasion in different habitats are discussed.

2.1. A brief history of invasions

The destruction of the main habitats of Seychelles and invasion by woody plant species are closely linked to human activities, which began with the first settlers (Sauer 1967).

- Humans first settled in Seychelles between 1742 and 1770. These settlers initially lived on what nature provided: wood, giant tortoises and crocodiles. The first agricultural crops were sugar cane (*Saccharum officinarum*), coffee (*Coffea* spp.), cotton (*Gossypium* spp.), rice (*Oryza sativa*) and some fruit trees.
- In 1772, *Syzygium aromaticum* (cloves), *Myristica fragrans* (nutmeg) and *Cinnamomum verum* (cinnamon) were planted in a small experimental garden, 'Jardin du Roi', on Mahé. The first attempts to cultivate these trees were not very successful; only *C. verum* survived, and it subsequently escaped and naturalized.
- The first recorded export crop was cotton, appearing in cargo lists for the first time in 1796 and becoming the main export from 1802. By 1810, the islands had nearly 1 200 ha planted with cotton, roughly equal to the area planted with food crops. Cotton production declined in the face of American competition and by 1831 it had taken second place to sugar cane.
- In 1819, most of Mahé was described as being cleared of its original forest. *Cocos nucifera* was reported as still strictly a seashore tree.

- By 1840, the inhabitants claimed that they had established *C. nucifera* plantations capable of producing several hundred thousand litres of coconut oil annually. In 1842, the island of Sainte Anne was described as a forest of coconuts, although cotton and coffee were still listed ahead of coconuts in the colony's commercial products.
- *Vanilla planifolia* (vanilla) and *Pogostemon cablin* (patchouli) were introduced during the eighteenth century and in 1904, respectively, and both suffered subsequent ups and downs in production.
- Cinnamon was identified as a very valuable crop only in 1902. Some cinnamon had been exported in the early nineteenth century, and a small factory was distilling cinnamon oil before 1900, but the activity had never taken off. The history of cinnamon in Seychelles is curious as it was introduced early on and deliberately, but exploitation was long delayed and then involved feral rather than cultivated stands. By the late nineteenth century, *Cinnamomum verum* commonly dominated secondary vegetation and volunteered in *Cocos nucifera* plantations on Mahé and Silhouette.
- Cinnamon has been the main export after copra in most years since 1908. Bark cropping reached a peak in 1908. After 1915, exploitation shifted out of necessity to distillation of leaf oil from shoot regrowth and seedlings too small to yield good bark.
- About 50 Cinnamon distilleries were still operational in the 1960s. Trees were felled for their leaves about every one and a half years. Five years of shoot regrowth was sufficient to shift back to bark cropping. Bark production recovered strongly after 1942.
- The end of the cinnamon industry coincided with the opening of the international airport in 1972 and the subsequent development of the tourist industry, which provided better returns and deterred people from cropping cinnamon.
- Since the opening of the airport, there has been a continuous stream of introductions of exotic species, both deliberately (ornamentals) and accidentally. Some of these species have already proved to be highly invasive.
- Throughout the colonial period and especially during the twentieth century, introductions of species were made for a range of uses including: as timber trees (e.g. *Paraserianthes falcataria*), for stabilization and conservation of soils (e.g. *Tabebuia pallida, Chrysobalanus icaco*) and as windbreak barriers (e.g. *Casuarina equisetifolia*). All of the species given as examples above have since proved to be invasive.

Friedmann (1994) recorded 320 dicotyledonous woody plant species in the granitic islands, 90 native species (of which 50 percent were endemic) and 230 exotic species (72 percent of the total species). Robertson (1989) listed monocotyledonous plant species (mainly palms and pandans) in these islands, including 11 native species (of which 90 percent were endemic) and 35 exotic species (76 percent of the total). In all, 370 woody plant species have been reported from the granitic islands. Of these, 105 are native (54 percent of these are endemic) and 265 are exotic (72 percent of the total species). Among the exotic woody plant species, 60 percent are ornamentals, ten percent are timber trees, 15 percent are fruit trees and the remaining 15 percent were mainly introduced as spice crops or medicinal plants. Since the publication of Friedmann (1994) many new as yet unlisted exotic woody plant species, especially ornamentals, have been introduced.

2.2. Invasiveness

The exotic woody plant species have been divided into four categories, which will be discussed in turn: (1) main invasive species, (2) non-consensus species, (3) apparently non-invasive species, and (4) potentially new invasive species. In addition, a brief account of the main invasive non-woody plant species of Seychelles is given.

2.2.1. Main invasive woody plant species

Thirteen woody plant species are widely accepted as problematic invasive species (Table 1). They are widespread, are continuing to spread and have a negative impact or invade sensitive areas. In addition, there are three species that are naturalized but spreading only slowly, included herein as 'naturalized, regenerating but slowly spreading woody plant species', and another four new invasive species grouped as 'expanding woody plant species'.

TABLE 1. THE MAIN INVASIVE WOODY PLANT SPECIES OF SEYCHELLES
The list is ordered according to decreasing concern, with the most problematic species in bold

Species	Date of introduction[a]	Mode of dispersal	Invaded islands	Invaded habitats[b]
Cinnamomum verum	1772 (6)	birds	granitics	all habitats
Paraserianthes falcataria[c]	1911 (1)	wind	Silhouette, Mahé	I
Psidium cattleianum	1870 or before (2)	birds	granitics	I, P, M
Syzygium jambos	1870 or before (2)	frugivores	granitics	I, M
Casuarina equisetifolia	1768 (5)	wind, water	granitics, coralline	C
Alstonia macrophylla[c]	1962 or before (3)	wind	granitics	C, G
Chrysobalanus icaco	1911 (4)	gravity, rats(?), frugivores(?)	granitics	C, I
Leucaena leucocephala	1918 (1)	gravity(?)	granitics, coralline	C
Cocos nucifera	1609 (6)	gravity, water	granitics, coralline	C
Adenanthera pavonina	? (6)	gravity, birds(?)	granitics	I, P
Tabebuia pallida[c]	1911 (1)	wind	granitics, coralline	C, I, P
Lantana camara	1877 (7)	birds	granitics, coralline	C, I
Carica papaya	19th century (5)	frugivores	granitics, coralline	C

[a] Introduction date refers to earliest date found in the literature. 1: Henry (1976); 2: Carlstroem (1996); 3: Robertson (1989); 4: Sauer (1967); 5: Gerlach (1996a); 6: McAteer (2002); 7: Baker (1877).
[b] Habitats: C: Coastal forest; G: Glacis (inselberg); I: Intermediate-altitude forest; M: Mountain forest; P: Palm forest.
[c] Protected by Seychelles legislation (Breadfruit and Others Trees Act).

Six of the main invasive species are widely accepted as the most problematic woody plant species in Seychelles. The most abundant invasive woody plant species in all habitat types except coastal forests is *Cinnamomum verum*. *Psidium cattleianum* and *Syzygium jambos* are especially problematic in mountain forests, *Paraserianthes falcataria* in valleys, *Alstonia macrophylla* on glacis, and *Casuarina equisetifolia* in coastal habitats.

All main invasive species except *Alstonia macrophylla* and *Cocos nucifera* are classified as highly invasive (*Psidium cattleianum, Casuarina equisetifolia, Leucaena leucocephala, Lantana camara*) or moderately invasive in the tropics by Binggeli *et al.* (1998). They were introduced to Seychelles for a variety of purposes: as timber trees (four species), fruit trees (three), multipurpose trees (two), spice crops (one) and ornamentals (one), and for erosion control (one) or uncertain use (one). All species except *Alstonia macrophylla* were introduced to Seychelles at least six decades ago. More than two-thirds are dispersed by either wind or frugivores. One-third are nitrogen-fixing trees (*Paraserianthes falcataria, Casuarina equisetifolia, Leucaena leucocephala, Adenanthera pavonina*). Two-thirds of the species are trees with, in addition, one species of palm (*Cocos nucifera*), and four species of shrub (*Chrysobalanus icaco, Leucaena leucocephala, Carica papaya, Lantana camara*).

2.2.1.1. Naturalized, regenerating, but slowly spreading woody plant species

The three tree species, *Pentadesma butyracea, Sandoricum koetjape* and *Hevea brasiliensis,* dominate some secondary lowland forests on Mahé, Praslin and Silhouette, where they had formerly been planted. They were all introduced for the first time around 1910 (Henry 1976). Their seeds are apparently not actively dispersed, but *P. butyracea*, at least, is potentially very problematic, forming monospecific stands and expanding its range slowly. *Hevea brasiliensis* grows best along rivers. All these species need fertile soils.

2.2.1.2. Expanding woody plant species

In recent years, an expansion in the range of four bird-dispersed shrubs or small trees has been observed: *Ardisia crenata* (first introduced in 1960; Robertson 1989), *Clidemia hirta* (1987, Robertson 1989) and *Dillenia suffruticosa* (1960s–70s; Bailey 1971), and *Memecylon caeruleum* (1931; Gerlach 1996b). Three species were introduced as ornamentals or into the Victoria Botanical Garden, while *C. hirta* was accidentally introduced. These species are not yet widespread, apart from *C. hirta* on Silhouette, but all are thought to have the potential to become invasive in the near future.

Clidemia hirta was first reported from Silhouette in 1987 (Robertson 1989). On Mahé a single plant was eradicated in 1993 (Gerlach 1996b), and in 1999 another small infestation was reported (K. Fleischmann, personal communication). It now dominates an area of 2.5 ha on Silhouette, where it is frequent in all forest habitats (Gerlach 1996b), and it has been spreading on Mahé, an event that has been comprehensively mapped (M. Vielle, personal communication).

2.2.2. Non-consensus woody plant species

This category includes species where no consensus on invasive status has been reached yet. Either a species is invasive only in restricted areas or evidence of invasion is too scarce for consensus to be reached.

Anacardium occidentale, *Ochna ciliata* and *Ochna kirkii* grow infrequently on glacis. *Anacardium occidentale* was noted on Mahé as long ago as 1787 (Sauer 1967), and has been classified as moderately invasive (Binggeli *et al.* 1998). *Ochna ciliata* is indigenous to Aldabra. *Moringa oleifera* and *Ricinus communis* are widespread on some small and outer islands. They are classified as moderately invasive (Binggeli *et al.* 1998). *Annona squamosa* is widespread on North (J. Gerlach, personal communication). *Ardisia elliptica* (first introduced in 1915; Friedmann 1994) is spreading along the eastern slope of Morne Seychellois on Mahé. Individual trees of *Artocarpus heterophyllus* can be found in intermediate-altitude forests where they regenerate well. *Coffea canephora* seems to be spreading on Silhouette (J. Gerlach, personal communication), but is apparently not problematic on Mahé. *Psidium guajava* is invasive on some small islands (see Box 1: Invasive exotic plant species on small granitic islands of Seychelles).

2.2.3. Apparently non-invasive woody plant species

A group of exotic woody plant species has been identified that was introduced to Seychelles at least three decades ago and is now naturalized. However, these species are apparently not often reported to be regenerating and spreading. Nonetheless, they either are invasive in other parts of the tropics (Binggeli *et al.* 1998) or within the Indian Ocean, or have been widely planted in Seychelles. Among them are timber trees (*Eucalyptus* spp., *Pinus* spp., *Pterocarpus indicus*, *Swietenia macrophylla*, *Swietenia mahogani*), fruit trees (*Citrus* spp., *Mangifera indica*), trees naturalized around abandoned settlements in secondary forests (*Aleurites moluccana*, *Flacourtia jangomas*, *Syzygium aromaticum*), ornamentals (*Ravenala madagascariensis*, *Pandanus utilis*), *Camellia sinensis* (tea) in plantations on Mahé, and *Rubus rosaefolius*, naturalized in Seychelles since at least 1866 (Gerlach 1996a).

Swietenia mahogani does not seem to be invasive elsewhere in the tropics. However, *Swietenia macrophylla* is invasive in Sri Lanka (Cronk and Fuller 1995) and there is concern that it could become invasive in Seychelles if not properly managed. Despite their high seed production, *Eucalyptus* species have not been nearly as successful at invading exotic environments throughout the tropics as other widely planted trees such as pines and legumes (Richardson 1998). Many *Eucalyptus* species produce large quantities of seeds, so their lack of success as invaders is rather puzzling. *Pinus* species are very problematic in South Africa, but mainly because they invade grassland and scrub land (Richardson 1998). *Pterocarpus indicus* was reported to have invaded secondary forests of Seychelles in the nineteenth century (Sauer 1967).

2.2.4. Potentially new invasive woody plant species

Albizia lebbeck, Cananga odorata, Elaeis guineensis, Raphia farinifera, Spathodea campanulata (which is invasive in the Comoros archipelago) and *Melia azedarach* (syn. *M. dubia*) can sometimes be found naturalized in intermediate-altitude forests. These trees were first planted in Seychelles in the 1950s–70s (Swabey 1961; Robertson 1989), apart from *R. farinifera* which was recorded earlier by Summerhayes (1931). *Spathodea campanulata* is very invasive on some equatorial oceanic islands. *Allamanda cathartica* is a shrub that can sometimes be found naturalized in the forests; it is difficult to eradicate and may become a problem in the future. *Cola nitida* can be found in a few small dense patches on Mahé and Silhouette. *Litsea glutinosa* can often been found along roads and on some small islands (e.g. Sainte Anne).

The following species that are invasive on other islands of the region (see Parts 3–5 of this publication) have been planted or are naturalized in Seychelles: *Acacia mangium* (planted for erosion control on Praslin), *Citrus reticulata* (naturalized in secondary habitats), *Desmanthus virgatus* (naturalized along roads and in wasteland), *Eugenia uniflora* (naturalized in secondary habitats), *Gliricidia sepium* (frequently planted), *Jatropha curcas* (planted and naturalized), *Mimusops coriacea* (planted along the coast and naturalized), *Murraya paniculata* (naturalized), *Schinus terebinthifolius* and *Tamarindus indica* (both widely planted and naturalized, with fruits sold on the local market) and *Tecoma stans*.

Two native trees of Seychelles are invasive in other small island countries and territories of the region: *Flacourtia indica* (native to Aldabra, Alstove) and *Trema orientalis*.

2.2.5. Main invasive non-woody plant species

Although the scope of this study did not include herbaceous species, it is important to mention them briefly as they are also of major concern in Seychelles. Creepers, in particular, should be given careful consideration as they seem to escape their usual habitat (degraded land around towns and along roads) to establish in forests and key areas for biodiversity. Their further spread could be a serious problem if not appropriately controlled. It is worth noting that concern over creepers is recent, as the last forestry sector study (INDUFOR 1993) did not mention them. Their spread is undoubtedly rapid.

The main problematic non-woody plant species mentioned during this study were:

- Creepers: *Merremia peltata, Philodendron* sp., *Epipremnum* sp., *Thunbergia grandiflora, Quisqualis indica, Syngonium podophyllum* (Matyot 1999), *Pueraria phaseoloides* and *Passiflora edulis*
- Ferns: *Dicranopteris linearis*
- Aquatic plants: *Eichhornia crassipes* and *Pistia stratiotes*
- Grasses: *Panicum maximum*
- Other herbaceous plants: *Agave sisalana, Alocasia macrorrhiza, Ananas comosus, Caladium sp., Clerodendrum sp., Desmodium canum, Dieffenbachia seguine, Elettaria cardamomum Furcraea foetida, Stachytarpheta jamaicensis* and *Stachytarpheta urticaefolia*

There is a knowledge gap concerning non-woody plant species despite their obvious impact on the environment.

2.3. Degree of invasion

The only quantitative data available on the degree of invasions in different habitats on Mahé and Praslin are from a long-term study by the Geobotanical Institute, ETH (Swiss Federal Institute of Technology) Zurich (Fleischmann 1997; Reinhardt and Voellmy 2000; Wiederkehr and Anderegg 2001; Héritier 2002). Qualitative data are available for Silhouette (Gerlach 1993a; Gerlach *et al.* 1997). A comprehensive, quantitative study on small islands has recently been published (Hill 2002; see Box 1: Invasive exotic plant species on small granitic islands of Seychelles).

2.3.1. Coastal forest

The main invasive species found in the coastal zone are the shrubs *Carica papaya, Leucaena leucocephala, Lantana camara* and *Chrysobalanus icaco* and the trees *Cocos nucifera, Casuarina equisetifolia, Tabebuia pallida* and *Alstonia macrophylla* (see Section 1.2.2. Coralline and limestone islands and Box 1). *Tabebuia pallida* is very prominent on Praslin and along all coastal roads on Mahé (e.g. Wiederkehr and Anderegg 2001; Héritier 2002). *Carica papaya* became a dominant part of the vegetation on Cousin after major forest destruction by a storm in September 2002 (Schumacher and Kueffer 2002).

2.3.2. Lowland and intermediate-altitude forest

Almost all lowland and intermediate-altitude forests between 100 and 700 m asl are either former plantations or *Cinnamomum verum* forests with a few exotic tree species dominating the vegetation. The dominating trees are *Cinnamomum verum, Cocos nucifera, Tabebuia pallida, Sandoricum koetjape*, *Adenanthera pavonina*, *Swietenia macrophylla* and *Paraserianthes falcataria*. The most prominent species are *Cinnamomum verum, Sandoricum koetjape* and *Adenanthera pavonina. Paraserianthes falcataria* is mainly confined to valleys with well-developed soils. Other frequent invasive species are *Pentadesma butyracea, Chrysobalanus icaco, Psidium cattleianum* and *Syzygium jambos.* On Silhouette, *Psidium cattleianum* dominates some areas (Gerlach 1993a). On Silhouette there are also 7.4 ha of *Hevea brasiliensis* and 8.4 ha of *Coffea canephora* forest plantations (Gerlach *et al.* 1997). In lowland and intermediate-altitude forests, exotic species make up 60–90 percent of the vegetation, the native vegetation consisting mainly of endemic palms (Reinhardt and Voellmy 2000; Wiederkehr and Anderegg 2001).

A less degraded, low-stature (up to 5 m high) broadleaved forest still exists in this altitude range on Praslin. The main invasive species in this forest are *Cinnamomum verum, Adenanthera pavonina* and *Chrysobalanus icaco*, which make up 10–25 percent of the vegetation (Reinhardt and Voellmy 2000; Héritier 2002).

BOX 1: INVASIVE EXOTIC PLANT SPECIES ON SMALL GRANITIC ISLANDS OF SEYCHELLES

Including Tables 2, 3 and 4

By Michael Hill, Nature Seychelles

Previous studies on the problem of invasive plant species in granitic Seychelles have concentrated on the larger islands such as Mahé and Silhouette. The smaller (286 ha), lower-lying islands of the archipelago differ both environmentally and ecologically from the large islands; they are generally drier, more exposed to marine influence, and support fewer native vegetation types. The original vegetation of islands in this size range would probably have been dominated by forest and scrub (on medium-sized islands) with open, exposed glacis and (on coastal flatlands) freshwater or brackish marshes and beach margin communities, occasionally mangroves. Endemic plant species would probably have been rare on small, remote islands but more common on the relatively larger islands and on those very close to Mahé or Praslin. However, while invasive exotic plants have not generally displaced endemic plants, they harbour a less diverse insect fauna, which affects the food supply of some endemic insectivorous birds (Hill 2002).

The flora and vegetation of 19 small and medium-sized islands ranging from 0.4 to 286 ha were studied in the period 1999–2001 as part of the project 'Managing Avian Ecosystems in Granitic Seychelles' (Tables 2 and 3), and these data have been used to identify the most problematic invaders (Hill 2002) (see Table 4). Many of the islands visited had been extensively altered by humans, with extensive areas of remnant native vegetation surviving mainly on the medium-sized islands (Curieuse and Félicité) or in inaccessible areas of smaller islands (parts of Thérèse and Marianne, for example). The proportion of the flora made up of exotic species ranged from 13 to 80 percent. Generally, medium-sized islands (that had supported settled human populations and cultivation) and small islands close to Mahé and Praslin (which were climatically similar to the larger islands and received a larger influx of propagules than more distant islands) had a larger proportion of non-native plants than small, remote islands.

On most (but not all) of the islands, human influence had led to the forest destruction and its replacement with more open plantations of *Cocos nucifera*. On plantation islands, unwanted trees were removed and introduced herbaceous plants thrived. *Cocos nucifera* is probably native to the islands, but today it attains extremely high densities on former plantation islands, and the dense regrowth of seedlings beneath plantation palms may exclude other species. Many of the most widespread introduced species (i.e. those occurring on more than half of the islands studied) were herbaceous plants and non-woody creepers, some deliberately introduced to islands as useful plants; the most widespread exotic species found was *Asystasia* sp., present on 17 of the 19 islands. In general, herbaceous species are less likely than woody plant species to threaten invasion of closed forest or scrub communities, but some herbaceous invaders have established large colonies in more open habitats to the exclusion of native plants. Examples include *Asystasia* sp. in rocky, open areas of Cousine and Cousin, *Panicum maximum* on glacis on Frégate, *Ananas comosus*, once abundant on glacis on Aride (Warman and Todd 1984), and *Agave sisalana* and *Furcraea foetida* on open rocky slopes and coralline plateaux of a number of islands. The (possibly native) fern *Dicranopteris linearis*, regarded as a fire hazard on Mahé (Carlstroem 1996), was present on few small islands, although extensive colonies occurred on Petite Soeur and Thérèse.

Woody plant species present a greater threat to native ecosystems. The threat from exotic woody plants can be perceived from Tables 2 and 3. The most widespread introduced trees were *Casuarina equisetifolia* and *Tabebuia pallida*, each found on 15 islands. *Casuarina equisetifolia* occurs on even the smallest islands because of its ability to survive salt spray, but usually in small numbers. *Tabebuia pallida*, where present, tended to dominate large areas of vegetation (for example, on Marianne). The species has been widely planted and shows strong, rapid regeneration from seed, thus it was able to exploit resources that became available when *Cocos nucifera* plantations were abandoned. *Adenanthera pavonina* was also widespread, occurring on 14 islands. However, although it produces large quantities of viable seed, this tree was rarely a prominent component of forest communities on smaller islands.

In contrast, *Cinnamomum verum* occurred on fewer islands (and was generally absent from the smallest, remote islands), but was a prominent feature of vegetation where it did occur. It was dominant on the medium-sized islands studied and on islands close to Mahé and Praslin, and was probably the most abundant exotic tree species on the study islands. The tree *Alstonia macrophylla*, although currently restricted to a few of the small islands and rarely found in forest vegetation, showed potential for becoming an aggressive invader where it was present. It exhibited a rapid natural increase in dry, exposed environments on scrub-covered hillsides on North and glacis on Frégate.

BOX 1 (CONT.): INVASIVE EXOTIC PLANT SPECIES ON SMALL GRANITIC ISLANDS OF SEYCHELLES

Several introduced shrub species were particularly prominent components of vegetation on the islands studied. This is probably because vegetation on these islands is in the process of successional change, but shrubs may remain prominent in the longer term because of the mosaic nature of open and closed habitats on small islands. The most widespread and dominant shrub was *Chrysobalanus icaco*. This species, deliberately introduced to some islands (including Curieuse, Félicité) for erosion control on red earth slopes, was a major feature of most of the medium-sized islands studied, invading open slopes, glacis and even forest. *Morinda citrifolia*, an introduced species according to one recent source (Friedmann 1994), was widespread throughout the islands and was prominent on coastal plateaux (such as on Cousin) and the coralline island of Denis. *Carica papaya* also reached its greatest prominence on the coralline coastal plateaux of granitic islands and on the coralline islands of Bird and Denis, often beneath a forest canopy of *Cocos nucifera* or *Pisonia grandis.* Uniquely among the islands visited, North showed extensive invasion by scrub dominated by *Lantana camara* and *Psidium guajava*. *Psidium guajava* was also a component (with *Citrus* spp., *Mangifera indica* and other formerly cultivated and native species) of mixed species scrub on Marianne.

Perhaps because of environmental differences on smaller islands and/or poor dispersal, some of the woody plant invaders prominent in the hills of Mahé were absent or rare on the small islands studied. Thus *Clidemia hirta* was found on only one island (North), where a few individuals were present. *Psidium cattleianum*, although represented by mature fruiting trees on several islands, was rare in semi-natural vegetation (*Psidium guajava* was more frequent). *Syzygium jambos* was present only on Conception (where it dominated a small area of low forest) and Frégate. *Paraserianthes falcataria* was present on Curieuse, Frégate, North and Thérèse, islands to which it had been introduced, and showed strong regeneration on some of these.

Freshwater habitats on small islands tend to be small, often brackish and seasonally dry. Because of their small size, they are vulnerable to dominance by introduced herbaceous species, and a few marginal species that can survive occasional periods of drought are widespread including *Alocasia macrorrhiza*, *Colocasia esculenta* and *Ludwigia octovalvis*. However, none of these plants survives in deeper water, and the extremely invasive floating species of open water, *Eichhornia crassipes*, was recorded on only one island (Frégate).

The most problematic invasive woody plant species for conservation managers are detailed in Table 4. In many cases, the current local dominance of these species appears to be the legacy of widespread large-scale planting in the past (e.g. *Cocos nucifera*, *Citrus* and *Psidium* spp.). Other species (notably *Alstonia macrophylla*) are more recent introductions but current behaviour (number of propagules produced, speed of growth) suggests that they could become important problem species in the future. While small islands are to some extent protected from invasion of new species by a water barrier, it is apparent that introduced species can cross quite large distances (illustrated, for example, by the spread of the bird-dispersed shrub *Clidemia hirta* from Silhouette to North [Hill 2002]) and thus the list of invasive exotic plant species on small islands is likely to increase with time.

TABLE 2: MOST WIDESPREAD EXOTIC PLANT SPECIES ON 19 MEDIUM-SIZED AND SMALL ISLANDS OF SEYCHELLES

Species	No. of islands where present
Asystasia sp.	17
Vernonia cinerea	15
Turnera angustifolia	15
Tabebuia pallida	15
Casuarina equisetifolia	15
Adenanthera pavonina	14
Stachytarpheta jamaicensis	13
Plumeria rubra	13
*Phyllanthus niruri (*syn. *P. amarus)*	13
Passiflora suberosa	13
Morinda citrifolia	13
Catharanthus roseus	13
Carica papaya	13

TABLE 3: TEN MOST PROMINENT EXOTIC TREE SPECIES ON TEN MEDIUM-SIZED ISLANDS OF SEYCHELLES

Species	No. of islands where present	No. of trees in survey plots[a]
Cinnamomum verum	4	260
Tabebuia pallida	5	61
Carica papaya	3	59
Anacardium occidentale	7	51
Casuarina equisetifolia	3	51
Adenanthera pavonina	5	30
Alstonia macrophylla	2	11
Citrus spp.	1	11
Psidium guajava	2	11
Paraserianthes falcataria	2	10

[a] Plots were 302 × 100 m^2.

TABLE 4: WOODY PLANT SPECIES THAT HAVE PROVED INVASIVE ON SMALL ISLANDS OF SEYCHELLES
The list is in approximate order of current importance

Species	Type[a]	Habitats[b]				Notes
		Forest	Scrub	Glacis	Grass-land	
Cinnamomum verum	T	x	x			Prominent on larger islands and those close to Mahé and Praslin
Chrysobalanus icaco	S	x	x	x	x	Predominantly in open areas but can survive shade, becomes dominant through seed and vegetative reproduction
Tabebuia pallida	T	x	x			High fecundity from seed, widely planted
Alstonia macrophylla	T		x	x	x	Recent on small islands, drought tolerant, germinates in light, threat to open habitats
Adenanthera pavonina	T	x	x			Widespread, heavy seed production, may become threat
Paraserianthes falcataria	T	x	x			Huge seed production, not widely planted but may become local threat
Leucaena leucocephala	S		x		x	Can dominate open areas, especially coral islands, plateaux
Lantana camara	S		x	x	x	Threat to open areas and scrub on plateaux and hills, especially favoured by grazing, cannot survive heavy shade
Psidium guajava	S	x	x	x	x	Mainly in open areas, locally prominent where cultivated in past
Carica papaya	S/T	x	x		x	Thrives on coralline islands and plateaux, in clearings and open areas
Citrus spp.	T/S	x	x		x	Locally prominent where heavily planted in past

[a] S: Shrub; T: Tree.
[b] x: Invasive in that habitat.

2.3.3. Palm forest

Invasion levels of 15–25 percent have been recorded for palm forests on Praslin and Mahé (Fleischmann 1997; Reinhardt and Voellmy 2000; Héritier 2002). The main invasive species were *Cinnamomum verum, Adenanthera pavonina, Psidium cattleianum* and *Tabebuia pallida.*

2.3.4. Mountain cloud forest

To date only a few woody plant species have been able to invade mountain cloud forests, namely *Cinnamomum verum, Psidium cattleianum* and, to a lesser degree, *Syzygium jambos*. Nonetheless, some new invasive species such as *Clidemia hirta* and *Ardisia crenata* have recently been found in this habitat. In a mountain cloud forest on Mahé, 17 percent of mature woody plants were reported to be exotic (Fleischmann 1997).

2.3.5. Glacis (inselbergs)

The main exotic woody plant species on glacis are *Cinnamomum verum*, *Alstonia macrophylla* and, to a lesser degree, *Anacardium occidentale*. Glacis are also invaded by a fern (*Dicranopteris linearis*), a grass (*Panicum maximum*) and an herbaceous plant (*Furcraea foetida*). Glacis is the habitat most resistant to invasion, with exotic invasive species contributing only 2–9 percent of the mature woody plants while, for instance, in the forests adjacent to the glacis on Mt Sébert 77–89 percent of the mature woody plants are exotic species (Fleischmann *et al.* 1996; Fleischmann 1997).

2.3.6. Regeneration

A better understanding of regeneration and forest dynamics is needed for interpreting the data on current abundance of invasive species in the different habitats. A study is underway on seedling ecology and regeneration and on propagule pressure of invasive *vs.* native tree species (Kueffer *et al.* 2003; Schumacher *et al.* 2003). So far, data on seedling regeneration are scarce. On Praslin (Reinhardt and Voellmy 2000; Héritier 2002), the proportion of native species is generally larger among seedlings than among adult trees. However, the proportion of native species is markedly larger among saplings than among seedlings. The observed good regeneration of native species on Praslin is mainly explained by the presence of endemic palms (Héritier 2002). However, similar patterns have been observed around Mare aux Cochons on Mahé, where the native species are broadleaved trees and shrubs (C. Kueffer, unpublished data). Seedling communities are generally dominated by *Cinnamomum verum*. For instance, in an intermediate-altitude forest with a canopy dominated by native species, *C. verum* accounted for 30 percent of the adult trees but 80 percent of the seedlings (Wiederkehr and Anderegg 2001).

2.3.7. Outer islands

The percentage of introduced species among species restricted to the limestone islands is 17 percent, among those restricted to the coralline islands 92 percent, and among those present on both types of islands 63 percent. A very large proportion of the total flora of this group of islands consists of exotic species introduced to only one or two islands (Stoddart and Fosberg 1984).

The exotic woody plant species that have been found on more than ten islands are the trees *Casuarina equisetifolia, Cocos nucifera, Moringa oleifera* and *Terminalia catappa*, and the herbaceous plants, shrubs or small trees *Carica papaya*, *Datura metel* and *Ricinus communis* (Stoddart and Fosberg 1984). *Cocos nucifera* forest is the dominant vegetation on most islands. *Casuarina equisetifolia* also forms forests and *Carica papaya* and *Ricinus communis* form large monospecific stands on some islands. According to Friedmann (1994), *Lantana camara* is problematic on Aldabra. *Leucaena leucocephala* is becoming a concern on some coralline islands. The outer islands are too dry for most fruit trees, and their main problems stem from non-woody plants, especially *Agave sisalana* and others such as *Stachytarpheta jamaicensis, Turnera angustifolia* and *Senna occidentalis*.

On Aldabra, exotic species are mainly restricted to the coastal areas. As a conservation measure, transects for scientific purposes that cross the island are avoided because they could become pathways for invasions (L. Chong Seng, personal communication).

3. ENVIRONMENTAL AND ECONOMIC IMPACTS

Knowledge about impacts of invasive species in Seychelles is anecdotal and has never been quantitatively evaluated. No calculations of economic costs and benefits are available. Impacts on the endangered native flora and fauna are by far the most important concerns in Seychelles regarding invasive species.

3.1. Positive impacts

Economic value:
- Wood and wood products
- Source of fruit for people and animals
- Source of nectar and pollen for bees
- Agroforestry products

Habitat restoration:
- Colonization of eroded land
- Protection of water catchments
- Nursery trees for habitat restoration
- Refuges for endemic species

Aesthetic value:
- Ornamentals
- Spice plants and feature trees, such as *Paraserianthes falcataria* and *Pterocarpus indicus*, important for ecotourism

Wood production has ceased almost completely. Currently, cheaper foreign wood is imported. However, in terms of sustainable wood production and invasive timber tree species control, the potential of local resources should be borne in mind. Efforts could and should be made to improve perceptions of local woods and the cost of wood processing (see Section 7.2. Case Study: Timber tree species in Seychelles). At the forestry station at Grande Anse, Mahé, there is a small 13-year-old experimental plantation of the endemic tree *Mimusops sechellarum.* The establishment of forest plantations of apparently non-invasive exotic species such as *Swietenia mahogani* and *Pterocarpus indicus* could be considered, if careful monitoring were assured.

Some of the main invasive species, such as *Psidium cattleianum* and *Syzygium jambos*, are fruit trees. *Paraserianthes falcataria* is thought to be an important source of nectar and pollen for bees. Some species are used for non-wood products, for example *Cocos nucifera*.

It has to be remembered that exotic species were largely responsible for the restoration of the deforested and often eroded environment following the excessive timber tree exploitation of the nineteenth century. These trees helped to stop erosion, protected the water catchments and provided secondary habitats for endemic forest species.

Today, exotic species are still used for erosion control on dry and steep slopes on Praslin. Highly invasive species such as *Chrysobalanus icaco* have been substituted mainly by *Acacia mangium* and *Acacia polystachya* (Héritier 2002). The successful replanting of a dry site near Fond Ferdinand on Praslin during the 1990s with the endemic tree *Mimusops sechellarum* has also been reported (K. Beaver and L. Chong Seng, personal communication). Replanting with endemic palms, especially *Phoenicophorium borsigianum*, has been suggested as another alternative to exotic species (K. Fleischmann, personal communication). *Casuarina equisetifolia* is used as a windbreak and to stabilize reclaimed land.

The ornamentals currently planted in Seychelles are still largely exotic. Compared with endemic species, they grow more easily and quickly, are better known and produce large colourful flowers. Naturalized spice trees along ecotourism trails are an attraction. *Pterocarpus indicus* trees form a famous alley in a tourist site at Mission Lodge in the Morne Seychellois National Park.

3.2. Negative impacts

Impacts on ecosystem processes:
- Increased fire risk
- Increased erosion
- Changes in the water budget
- Increases/decreases in soil nutrient availability
- Changes in the forest structure

Population level impacts (see Section 3.3. below):
- Outcompeting native plant species
- Effects on frugivores
- Effects on herbivores
- Effects on insectivores

Genetic effects:
- Hybridization

Impacts in human-dominated habitats:
- Agricultural weeds

An increase in fire risk has been reported in connection with *Dicranopteris linearis*. An increased frequency of fire is generally considered to be a problem in Seychelles because of the subsequent increased erosion. Preliminary data from a recently conducted master study on post-fire succession on Praslin indicated that vegetation density and diversity and soil nutrient content would recover within about ten years. Immediately after the fire, soil nutrient content and vegetation density and diversity were strongly reduced. There were some indications that fire gaps were beneficial for the regeneration of exotic species, although native species showed a higher capacity for reshooting after the fire (Meuwly 2002).

BOX 2: A POTENTIAL ECOSYSTEM TRANSFORMER SPECIES, *PARASERIANTHES FALCATARIA*

Paraserianthes falcataria is relatively well studied in other tropical countries. One study demonstrated that, after 13 years, soils under a *P. falcataria* stand contained enhanced pools of total soil carbon (C) and nitrogen (N) and increased levels of inorganic N (Garcia-Montiel and Binkley 1998). Another study indicated that *P. falcataria* may be able to obtain more phosphorus (P) from a low-P soil by increasing the absorbing area of roots and mycorrhizae (Binkley *et al.* 2000). Using replicated plantations of *Eucalyptus saligna* and *P. falcataria* in Hawaii, it was shown that soils under the influence of *P. falcataria* had higher supplies of available N, but lower supplies of available P (Binkley 1997). *Paraserianthes falcataria* has a relatively sparse canopy, thus its light transmittance is high (Otsamo 1998). Similar patterns have also been discerned using preliminary data from Seychelles. Wiederkehr and Anderegg (2001) found increased total N content in soils below *P. falcataria*, and the amount of photosynthetic active radiation (PAR) on the forest floor was highest at a heavily invaded site and lowest at sites free of *P. falcataria*. Additionally, fallen large *P. falcataria* can be found frequently in the forest, forming large gaps, which is unusual for the forests of Seychelles.

A major concern arising from the above effects of *P. falcataria* is the possible facilitation of further invasions by other exotic species. Increased availability of nutrients and light might be favourable for invasive species (Davis *et al.* 2000). Facilitation between exotic species has been shown frequently (Simberloff and Holle 1999; Richardson *et al.* 2000), the most famous example being the N-fixing shrub *Myrica faya* in Hawaii (Vitousek and Walker 1989).

Paraserianthes falcataria is thought to lower the water table (INDUFOR 1993), although there is no quantitative evidence. Data are available on its impact on soil nutrient availability and forest structure (see Box 2: A potential ecosystem transformer species, *Paraserianthes falcataria*).

Thicket-forming shrubs such as *Clidemia hirta, Chrysobalanus icaco* and *Syzygium jambos*, *Lantana camara* in some lowland forests, *Dicranopteris linearis* and creepers all stop regeneration of trees in forest gaps and change the forest structure considerably. For example, no other vegetation grows under *Casuarina equisetifolia* trees.

Anecdotal observations reported by F. Friedmann suggest that there might be a risk of hybridization between the endemic *Pandanus balfourii* and the exotic *Pandanus utilis* (K. Beaver and L. Chong Seng, personal communication). *Impatiens walleriana,* which is cultivated in Seychelles, hybridizes under experimental conditions with the rare endemic *Impatiens gordoni* (A. Griffiths, personal communication).

Some invasive species are vigorous agricultural weeds, leading to loss of potential agricultural land. The main agricultural weeds are creepers and herbaceous plants, although some are woody plant species including shrubs such as *Lantana camara*.

3.3. A closer look at impacts on biodiversity

Almost all forest habitats in Seychelles are secondary and heavily invaded by exotic species. Management of invasive species is mainly concerned with the conservation of a rarefied native flora and fauna. In this context, there is a special focus on less invaded, sensitive areas of high biodiversity value, namely mountain cloud forests, palm forests and glacis, and on species that are capable of invading these habitats.

In addition to introducing exotic plant species, many other human activities complicate the picture. One species of parakeet, one species of white-eye (*Zosterops modestus*), a purple swamp hen, a subspecies of turtle dove, a giant tortoise (*Dipsochelys elephantina*) and a crocodile have become extinct (Stoddart 1984b; Skerrett *et al.* 2001). On the main granitic islands, several other insectivorous and omnivorous endemic birds have become extinct. Lionnet (1984) hypothesized that many Lepidoptera died out with deforestation in the nineteenth century, although there are no data to support this assertion. Carnivorous rats, dogs and cats, exotic carnivorous snails (*Gonaxis quadrilateris* and *Euglandina rosea*), the omnivorous tenrec (*Tenrec ecaudatus*), the carnivorous barn owl (*Tyto alba*) and several frugivorous birds have been introduced. Many endemic plant species are highly endangered and survive only in atypical refuge habitats. All these changes in forest structure, pollination, seed dispersal, herbivory and predation have modified ecosystems in an unknown manner. Climate change could further alter habitat conditions in the near future.

Exotic species might be involved in positive as well as negative changes in forest structure and dynamics. Changes in forest structure and associated changes in microclimate might have an impact on species groups such as endemic amphibians, endemic insects (see Box 3: The impact of invasive plants on native insects in Seychelles) and endemic snails. Most of the endemic amphibians need deep accumulations of moist leaf litter or rotten logs (Nussbaum 1984a). The structural diversity of the habitat was found to be the best predictor of species diversity of web-forming spiders (Muehlenberg *et al.* 1977).

Changes in tree demography and the numbers of rotting trees and logs, and in the abundance of exotic creepers are likely to have a considerable impact on rare parasitic plants and epiphytes, such as orchids, ferns, mosses, liverworts, lichens and fungi. Until now, observations have been incidental and no formal studies have been carried out. Moreover, the importance of the role of epiphytes in the forest ecosystem of Seychelles is not understood. If the diversity and abundance of epiphytes changes as a result of changing tree diversity and age structure within the forest, this will affect the range of invertebrates living in close association (see also Box 3).

Nests of the rare endemic Seychelles Scops owl (*Otus insularis*) have been found only in cavities of old, large individuals of the endemic *Dillenia ferruginea* and the exotic *Pterocarpus indicus* (Currie 2002), suggesting the importance of old trees, whether endemic or exotic, for this rare bird.

The degree of association between endemic insects and their host plants was discussed as early as 1933 (Scott 1933). No general conclusion can be drawn (see Box 3), except that the more plastic species are often more widespread and less endangered.

Most animal–plant associations have been described for endemic palms and pandans. Not only insects but also land leeches, nemerteans, earthworms, snails and woodlice have been recorded from the leaf axils of palms and pandans (Richardson 1978; Stoddart 1984c). However, the prevalence of records from palms and pandans may be biased, either because of the interest of researchers in these plant families or because palm forests are among the best-preserved habitats.

In coastal areas, native invertebrate diversity and abundance are markedly higher on native than on exotic trees (Currie 2002). On the other hand, *Tabebuia pallida* is an exotic tree with an abundant insect fauna (E. Henriette, personal communication), and *Cinnamomum verum* is also a relatively good tree for invertebrates (Rocamora and François 2000).

Seeds of *Lantana camara* and *C. verum* are an important food source for the endemic white-eye (*Zosterops modestus*) (Rocamora *et al.* 2001). However, the profusion of exotic fruit trees artificially increases densities of exotic bird species such as the Indian mynah (*Acridotheres tristis*) but also the endemic bulbul (*Hypsipetes crassirostris*), both of which prey on nests of other species including the Seychelles white-eye (G. Rocamora, personal communication).

In general, insectivorous species seem to be more endangered than frugivore species, in the case of both birds (See Box 4: Synopsis of interrelationship between native birds and exotic vegetation in Seychelles) and bats, illustrated by the relative abundance of the common frugivorous fruit bat (*Pteropus seychellensis* subsp. *seychellensis*) and the very rare insectivorous sheath-tailed bat (*Coleura seychellensis*). *Pteropus seychellensis* subsp. *seychellensis* is well adapted to exotic vegetation. It roosts in tall trees such as *Paraserianthes falcataria* and *Casuarina equisetifolia*, and feeds on, or at least pollinates, exotic species such as *Anacardium occidentale*, *Pentadesma butyracea, Sandoricum koetjape, Mangifera indica, Carica papaya, Artocarpus heterophyllus, Syzygium jambos* and *Psidium cattleianum*, but also native species such as *Northea hornei* and *Calophyllum inophyllum* (Racey and Nicoll 1984). Fruit bats are probably important dispersers of invasive plants. *Pteropus aldabrensis* on Aldabra pollinates the highly invasive *Agave sisalana* (Racey and Nicoll 1984).

The two endemic snakes (Nussbaum 1984b) and the endemic lizards (Cheke 1984) seem to cope with altered habitats.

BOX 3: THE IMPACT OF INVASIVE PLANTS ON NATIVE INSECTS IN SEYCHELLES
Including Tables 5 and 6
By Pat Matyot, Island Conservation Society (ICS)

A conservative estimate puts the number of insect species in the granitic and coralline islands of Seychelles at close to 4 000 (Cogan 1984). Very high levels of endemism have been suggested for many orders, but a definitive assessment of this would be possible only if the taxonomy of the insect fauna were to be scrutinized using modern molecular techniques (e.g. the study of mitochondrial and ribosomal DNA) and if the faunas of neighbouring land masses, such as Madagascar, were to become better known. Nonetheless, it is generally agreed that most of the insects of Seychelles are native species, i.e. "in terms of numbers of species, the species recently introduced by man are an insignificant proportion of the faunal total …" (Cogan 1984). Some insects, such as the giant tenebrionid beetle *Polposipus herculeanus* (Solier 1848), the four stick insects of the genus *Carausius* and the leaf insect *Phyllium bioculatum* (Gray 1832) are potential 'flagship' species – charismatic species that, because they are popular with humans, can be the focus for conservation efforts.

Scott (1933) appears to have been the first to point out that "most of the endemic insects [of Seychelles] are restricted to the remains of the endemic forests, while most non-endemic insects occur among non-endemic plants, either naturally distributed or artificially imported." One reason for this is that, as a result of coevolution, many plant-eating (phytophagous) native insects consume only a narrow range of native food plants (see Table 5). Predatory species that feed only or mainly on such specialist plant feeders, and specialized parasitoids that attack them, would also tend to have a restricted distribution.

The most immediate impact of encroachment by invasive exotic plants on native insects is to suppress the growth of the host plants of at least some plant-feeding insects by shading or crowding them out physically through nutrient competition or biochemically by allelopathy. Because specialist feeders are unable to overcome the physical and phytochemical ('allelochemical') defences of exotic invaders, this results in a reduction in the food supply for the insect species concerned, with its attendant impact on their survival rate and those of the predators and parasitoids that depend on them. The endemic hemipteran bug *Leptocoris toricollis*, discovered on Mahé by Charles Alluaud in 1892 (Bergroth 1893), has now disappeared from that island following the extinction of its food plant, *Allophyllus pervillei*, in the wild there – it survives only on other islands, such as Silhouette, Praslin and La Digue, where the plant still grows naturally. The apparent extinction of the butterfly *Phalanta philiberti*, once common on Mahé, Silhouette and Praslin, and the near-extinction of another butterfly, *Euplaea mitra*, which used to be common on Mahé and Silhouette, may also be due to the reduction in the abundance of their (unknown) food plants, although it is possible that introduced parasitoids may also have played a role in their decline.

Another reason why native insects are found mainly in areas of native vegetation is that many species are adapted to the microclimate produced by the vegetation architecture in such patches, and cannot survive elsewhere because of their narrow tolerance ranges, although in some cases the distribution of insect and plant species may coincide because they require similar physical conditions resulting from, for instance, elevation above sea level and aspect in relation to sun exposure and wind direction. Certainly microclimatic variables such as light intensity, ambient temperature, humidity and wind speed would be determined not only by the total amount of stems and foliage present, but also by the sizes/heights, plant habits, densities and seasonal phenologies of the plants present and the size, shape, thickness, position, arrangement and physiological activity (e.g. amount of evapotranspiration) of their leaves (Strong *et al.* 1984). Specific sites, such as different parts of a forest canopy, the narrow joints between the leaf bases of palms and pandans, moss-covered tree trunks, crevices under bark, spaces in leaf litter, and fallen branches and twigs constitute microhabitats that harbour insects adapted to them in terms of their specific microclimates as well as their physical structure.

BOX 3 (CONT.): THE IMPACT OF INVASIVE PLANTS ON NATIVE INSECTS IN SEYCHELLES

Replacement of native vegetation, especially that in the climax stage of succession, by exotic species with different growth forms, phenologies, etc., results in alterations in the microclimatic factors described above and the loss of microhabitats. In particular, the loss of water by evaporation through the cuticles of insects is markedly affected by the amount of water vapour in the air (Wigglesworth 1974) and a drop in relative humidity caused by loss of foliage cover or by a reduction in evapotranspiration can be deadly to insects adapted to conditions in humid forest. In laboratory conditions, the eggs of the stick insect *Carausius gardineri* do not hatch if the relative humidity of the air surrounding them is less than 90 percent (P. Matyot, unpublished data). A number of insects are part of the fauna of palm and pandan leaf axils and are rarely (in some cases never) found elsewhere (Scott 1933; Matyot 1998).

At the level of metapopulation dynamics, invasion by exotic plant species contributes to splitting suitable habitat into smaller 'islands' separated by barriers of unsuitable habitat because, as discussed above, the plants that make up these barriers are unpalatable and the microclimatic conditions prevailing there are unfavourable for survival. Many insect species, especially flightless ones, are not able to cross such barriers. On Silhouette, the spiny stick insect *Carausius scotti* is absent from formerly cultivated areas in the vicinity of Mare aux Cochons although these have been recolonized by one of its preferred food plants, the bird's nest fern *Asplenium nidus*, and the localities concerned appear to be suitable habitat for the insect (P. Matyot, unpublished data). Barriers of invaders such as *Cinnamomum verum* and *Clidemia hirta* may have prevented *Carausius scotti* from moving into these areas. Such interruptions in contiguity disrupt dispersal between populations of vulnerable species. As dispersal success is reduced, populations become increasingly isolated and this may result in genetic impoverishment and the non-replenishment of populations where there are chance local extinctions.

However, not all native insects have narrow diet and microclimatic tolerances. Table 6 gives some examples of polyphagous species (generalist feeders) among the insects of Seychelles that have switched successfully to introduced plants. Judging from its present abundance on *Chrysobalanus icaco*, one suspects that the grasshopper *Euschmidtia cruciformis* may have benefited from the introduction of the plant. This could be an instance of an invasive exotic species playing the role of connecting corridors across formerly inhospitable bare, eroded ground! As "the plant–insect interaction is the dominant biotic interaction" (Samways 1994), further work is required to elucidate the influence of plant communities on insect distribution in Seychelles. More research is required on the biology and ecology of individual species of plant-feeding insects, and the range of species 'recruited' by native and exotic plant species needs to be further scrutinized so that we can answer such questions as: Which species are most threatened in specific configurations involving invasive exotic species? What is the potential impact of further encroachment by particular invaders? What will happen if a particular exotic invader is suppressed or eliminated? This research needs to be carried out now, while there still remain patches of native vegetation where populations of native insects have not yet plunged below the minimum viable threshold.

TABLE 5: FOOD PLANTS OF SOME PHYTOPHAGOUS ENDEMIC INSECTS OF SEYCHELLES WITH RESTRICTED HOST RANGES

Insect species	Order	Host plant(s)	Degree of specialization [a]
Amirantea gardineri	Hemiptera	*Aphloia theiformis madagascariensis* var. *seychellensis* (Flacourtiaceae)	Monophagous
Leptocoris toricollis	Hemiptera	*Allophyllus pervillei* (Sapindaceae)	Monophagous
Privesana infusca	Hemiptera	*Pandanus hornei* (Pandanaceae)	Monophagous
Stenozygum aldabranum	Hemiptera	*Capparis cartilaginea* (Capparidaceae)	Monophagous
Nyctemera seychellensis	Lepidoptera	*Gynura sechellensis* (Compositae)	Monophagous
Enoplotettix gardineri	Orthoptera	Endemic palms (Arecaceae/Palmae) and pandans, *Pandanus* spp.	Oligophagous
Odontolakis aff. *sexpunctatus*	Orthoptera	Endemic palms (Arecaceae/Palmae) and pandans, *Pandanus* spp.	Oligophagous
Carausius gardineri	Phasmatodea	Various ferns (Pteridophyta)	Oligophagous
Carausius scotti	Phasmatodea	Various ferns (Pteridophyta)	Oligophagous
Graeffea seychellensis	Phasmatodea	Endemic palms (Arecaceae/Palmae)	Oligophagous

[a] Monophagous: Restricted to a single host plant;
Oligophagous (stenophagous): Feeds on a few similar/related plant species/families.

TABLE 6: INTRODUCED FOOD PLANTS OF SOME POLYPHAGOUS ENDEMIC INSECTS OF SEYCHELLES[a]

Insect species	Order	Introduced host plant(s)
Euschmidtia cruciformis	Orthoptera	*Chrysobalanus icaco* (Chrysobalanaceae)
Pelerinus rostratus	Orthoptera	*Cinnamomum verum* (Lauraceae) *Clidemia hirta* (Melastomaceae) *Syzygium jambos* (Myrtaceae)
Carausius alluaudi	Phasmatodea	*Tabebuia pallida* (Bignoniaceae)
Phyllium bioculatum	Phasmatodea	*Syzygium jambos* (Myrtaceae) *Syzygium cuminii* (Myrtaceae) *Psidium guajava* (Myrtaceae)
Macroglossum alluaudi	Lepidoptera	Adult on flowers of *Lantana camara* (Verbenaceae)
Cephonodes tamsi	Lepidoptera	Adult on flowers of *Lantana camara* (Verbenaceae)

[a] All data from Matyot (1998) except Lepidoptera records (J. Gerlach, personal communication).

BOX 4: SYNOPSIS OF THE INTERRELATIONSHIP BETWEEN NATIVE BIRDS AND EXOTIC VEGETATION IN SEYCHELLES

By James Millett, Rachel Bristol and Nirmal Jivan Shah, Nature Seychelles

The native birds within Seychelles have been relatively well studied, and the ecological requirements are well documented in comparison with other vertebrate groups. Overall, there is a correlation between several endemic species and vegetation communities dominated by native species. However, the impacts of exotic predators, exotic plant monocultures and a few plants of uncertain origin do complicate the overview. The purpose of this Box is to summarize the key elements of the current state of knowledge of the interactions between endemic birds and non-native trees.

Endemic birds

Falco araea, Seychelles kestrel: Seychelles kestrel has a total population of some 470 pairs and occurs throughout Mahé and Silhouette, with a small population on Praslin (Watson 1991; Kay *et al.* 2002). The relationships between vegetation communities and demography and/or distribution of the kestrel are unclear. Productivity is higher in the upland areas of Mahé than in the lowlands; higher densities of exotic predators are implicated in the lower breeding success in the lowlands (Watson 1981, 1991). Studies of a large sample of marked birds demonstrated that there was no significant difference in territory size in relation to altitude on Mahé (Watson 1981). A recent study on Silhouette claimed that coastal territories were significantly smaller than upland territories (Gerlach 2002). However, this work used a small sample size and unmarked birds (unlike the Mahé study) and findings should be treated with caution. Feare *et al.* (1974) analysed territory sizes in relation to habitat, but with a small sample size (n=5), the results were inconclusive. Overall, there is no firm evidence for a measurable negative effect of non-native plant communities on kestrel biology (J. Watson, personal communication).

Alectroenas pulcherrima, Seychelles blue pigeon: This widespread species is present on almost all inner islands (Skerrett *et al.* 2001). Its numbers and distribution have increased markedly on Mahé since the 1970s when it was a bird of the mountains, and it now extends down to the coast (C. Feare, personal communication). No significant work has been undertaken on the species. Relationships with vegetation communities are unclear, although it is apparently capable of adapting to modified vegetation communities and consuming fruits from exotic species.

Otus insularis, Seychelles Scops owl: This owl occurs only on Mahé. Its range tends to be sympatric with native or semi-native vegetation communities (Currie 2002; Currie *et al.* 2004) and demonstration of the importance of large native herbivorous invertebrates in the diet (e.g. orthopterans) may suggest that native forest is important (Currie *et al.* in press).

Aerodramus elaphrus, Seychelles swiftlet: There are few data on this species and relationships to vegetation are unclear.

Hypsipetes crassirostris, Seychelles bulbul: The bulbul is widespread on the four largest islands, and its range and numbers, like the blue pigeon's, have increased markedly since the 1970s (C. Feare, personal communication). There are too few data for firm conclusions to be drawn about relationships with vegetation, but anecdotal observations suggest that the species copes well with exotic species-dominated vegetation communities.

BOX 4 (CONT.): SYNOPSIS OF THE INTERRELATIONSHIP BETWEEN NATIVE BIRDS AND EXOTIC VEGETATION IN SEYCHELLES

Copsychus sechellarum, Seychelles magpie robin: A Critically Endangered species, the magpie robin is currently distributed on Cousin, Cousine, Aride and Frégate. A clear negative correlation exists between exotic dominated vegetation and food availability. On Frégate, an island dominated by exotic plant species, productivity and juvenile survival was improved by the provision of supplemental food. Exotic shrubs, e.g. *Chrysobalanus icaco,* and the grass *Panicum maximum* are particularly linked with reduced habitat quality and the leaf litter of exotic trees supported fewer vertebrates (e.g. McCulloch 1994; Komdeur 1995). This effect has been further demonstrated by Njoroge (2002) and Wagner (2002). Comparisons of invertebrate abundance between islands indicate that food availability is higher in the restored forests on Cousin and Aride than on Frégate.

Acrocephalus sechellensis, Seychelles warbler: Classified as Endangered, a relict population of the warbler survives on Cousin and there are reintroduced populations on Cousine and Aride. It is an insectivore, obtaining 98 percent of food items from foliage. Elevated food availability has been demonstrated to be linked to a number of native species, e.g. *Pisonia grandis*, but also to *Morinda citrifolia*, an allegedly introduced species. The warbler neither survives on, nor has been reintroduced to, islands with extensive broadleaved plant communities dominated by exotic species, so clear preferences cannot be discerned. However, the restriction of the warbler to the mangrove area of Cousin during the plantation era suggests the species can not prevail in a *Cocos nucifera* monoculture (Bathe and Bathe 1982; Komdeur *et al.* 1991; Komdeur 1994).

Terpsiphone corvina, Seychelles paradise flycatcher: One relict population survives on La Digue (BirdLife International 2000). A correlation between habitat use and *Calophyllum inophyllum*/*Terminalia catappa* forest has been demonstrated. Previous associations of the species with wetlands have been over emphasized. The only significant factor predicting range in recent studies was native forest with a high canopy. In addition, these native species have been demonstrated to be used preferentially for foraging and nesting (Currie *et al.* 2003a, Currie *et al.* 2003b).

Zosterops modestus, Seychelles white-eye: The species is restricted to Conception and Mahé; with a translocated population establishing on Frégate (BirdLife International 2000; Rocamora 2001). It has been demonstrated to cope well with modified habitats, and fruits from exotic woody plant species appear to be important dietary components on Mahé and Conception (Rocamora 2001).

Nectarinia dussumieri, Seychelles sunbird: This widespread species occurs on most granitic islands (Skerrett *et al.* 2001) Data are largely inadequate, but it appears to cope well with exotic plant communities. It forages on ornamentals and is frequently associated with human habitation and gardens.

Foudia sechellarum, Seychelles fody: The species is restricted to four islands within inner Seychelles and one of the Amirantes. The species is a generalist feeder, although a significant part of the diet is invertebrate, collected from foliage but also branches. The species also utilizes exotic plants such as *Carica papaya* and *Casuarina equisetifolia*. The relative importance of vegetation communities is not yet clear but current evidence suggests that native forest may be preferable, whilst some exotic plants could be advantageous (L. B. Wagner, personal communication).

Nesting habitats for water birds and seabirds

A number of tree-nesting seabirds breed within Seychelles. They all appear to use native species preferentially, although the situation is complicated by the utilization of *Cocos nucifera*. This is arguably a native species but frequently occurs in a monoculture that may be considered an exotic habitat, as wild *C. nucifera* would only occur as a component of beach crest vegetation communities.

BOX 4 (CONT): SYNOPSIS OF THE INTERRELATIONSHIP BETWEEN NATIVE BIRDS AND EXOTIC VEGETATION IN SEYCHELLES

Tree-nesting seabirds: Lesser noddy (*Anous tenuirostris*) and white tern (*Gyglis alba*) both appear preferentially to utilize broadleaved forest, typically dominated by native species, on Frégate, Cousine, Cousin, Aride, Bird and Recif. However, on Frégate exotic species, including *Pterocarpus indicus* and *Delonix regia*, are also used, while on Bird lesser noddies exhibit a preference for introduced *Cordia sebestena*. Brown (or common) noddy (*Anous stolidus*) uses a range of nesting sites including rock, tussocks and *Cocos nucifera* crowns. Other species of tree-nesting terns avoid nesting in palms, with a few exceptions such as lesser noddies on Recif. *Casuarina equisetifolia* leaf litter may suppress native vegetation and hence have a negative effect on habitat availability for nesting seabirds, boobies (*Sula* spp.) in particular, whilst the flexible branches are unsuitable for supporting nests (A. Skerrett, personal communication). However this species is used extensively for nesting by white terns and white-tailed tropicbirds (*Phaethon lepturus*). On Farquhar the red-footed booby (*Sula sula*) colony nests high in tall *C. equisetifolia* trees. *Casuarina equisetifolia* clearly also provides important roost sites for frigates (*Fregata* spp.), bridled terns (*Sterna anaethetus*), lesser noddies and smaller numbers of brown (common) noddies (C. Feare, personal communication).

Herons: A number of native herons also breed in woody plant species. Data are scarce for Seychelles but herons would appear to favour native species, e.g. night heron (*Nycticorax nycticorax*) on *Pisonia grandis*; cattle egret (*Bubulcus ibis*) on mangrove species; green-backed heron (*Butorides striatus*) on native species such as *Thespesia populnea* and *Scaevola sericea* that form a littoral hedge. However, exceptions have been recorded: on the small islets on the west of the lagoon on Farquhar, where at least some grey herons nest in *Agave sisalana*. On Cerf in the Providence group, in 1976 grey herons (*Ardea cinerea*) nested extensively in *Cocos nucifera* (C. Feare, personal communication).

Ground-nesting seabirds: Some evidence exists to suggest that exotic plants or artificial vegetation may discourage ground-nesting birds, e.g. *Agave sisalana* does appears to exclude sooty terns (*Sterna fuscata*) on Grand Ile, Cosmoledo. More importantly, sooty terns appear not to nest in *C. nucifera* plantations, and this may be one of the main factors that extirpated sooty terns from some of the Amirantes, e.g. Remire (C. Feare, personal communication). Feare *et al.* (1997) demonstrated that dense areas of introduced *Stachytarpheta jamaicensis* were avoided by sooty terns on Desnoeufs.

Conclusions

Such a crude assessment, including unquantified data, should be viewed with caution. The habitat/foraging preferences of several species have not been investigated, whilst others such as the warbler only prevail on islands with rehabilitated (semi-natural) habitats, and additional food sources such as fish and detritus from seabird colonies complicate the picture further for species such as the fody and magpie robin. Nonetheless, the available information indicates that several species have adapted to cope well with exotic vegetation, namely a frugivorous and a semi-frugivorous species and one nectar feeding species: Seychelles blue pigeon, bulbul and sunbird. The predominantly insectivorous species, Seychelles Scops owl, magpie robin, warbler, flycatcher and fody, display at least some preference for native dominated forest. Knowledge of the Seychelles kestrel and swiftlet is too data deficient to assess.

Examples of bird species benefiting from the introduction of exotic plant communities have been documented. In Europe, a number of bird species have shown range expansions following the establishment of exotic pine (*Pinus* spp.) plantations. More pertinent, in the Western Indian Ocean region in Mauritius, the nesting success of the endemic Mauritius fody (*Foudia rubra*) has been demonstrated to be significantly higher in exotic *Cryptomeria japonica* forest than in forest dominated by other exotic or native species. It has been suggested that this is because exotic predators are less abundant in the food-poor *C. japonica* forest, resulting in lower nest predation rates (Safford 1995). Within Seychelles, there has been no demonstration of exotic plant species communities providing a better habitat than native plant communities.

BOX 4 (CONT): SYNOPSIS OF THE INTERRELATIONSHIP BETWEEN NATIVE BIRDS AND EXOTIC VEGETATION IN SEYCHELLES

Some evidence exists to indicate that the species composition of exotic vegetation communities has a bearing on the density and diversity of bird species that are supported. For example *Cocos nucifera* monoculture, particularly where regeneration is occurring, appears to be particularly unsuitable for native birds whilst *Tabebuia pallida* has been demonstrated to support high densities of leaf dwelling invertebrates and might be expected to provide a reasonable quality habitat for native insectivores (Hill 2002). With the possible exception of the white-eye, which has been shown to prevail at equally high densities in exotic species-dominated and native vegetation, there are to date no clear examples of native birds being more successful in exotic than native plant communities.

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4. CONTROL MEASURES AND HABITAT RESTORATION

In the very early stage of an invasion, complete eradication of a new invasive species is sometimes possible. Most often, though, controlling the population density and further spread is all that is feasible. Control can be effected by introducing an exotic biological enemy (biological control), through application of herbicides (chemical control) or through mechanical removal (mechanical control).

4.1. Control measures

4.1.1. Biological control

So far, no attempt at the biological control of an invasive plant by the introduction of either an insect or a fungus has been undertaken in Seychelles. Planting of endemic palms that should be able to outcompete invasive species by altering the light levels under the canopy was suggested by Fleischmann (1999). In the past, livestock was possibly involved, alongside frequent mechanical removal, in controlling agricultural weeds in human dominated areas. Some of these weeds (invasive creepers and herbaceous plants) have started to spread only recently with the decrease in the number of grazing animals.

Seychelles has, however, had several negative experiences with attempts at the biological control of exotic animals through the introduction of predators (e.g. the barn owl, *Tyto alba*, and the carnivorous snails *Gonaxis quadrilateris* and *Euglandina rosea*).

4.1.2. Chemical control

Chemical control has been attempted with little success against *Cinnamomum verum* and *Psidium cattleianum* in a mountain cloud forest (see 7.1. Case Study: *Cinnamomum verum*). The injection of herbicides led to the death of nearby native plants. Similar experiences have been reported elsewhere, e.g. Costa Rica (Santos *et al.* 1986, cited in Goodland *et al.* 1998). A pilot study to control creepers (*Philodendron* sp.) by application of herbicide on cut stems is planned by the Forestry Section of the Ministry of Environment (M. Vielle, personal communication).

4.1.3. Mechanical control

Mechanical control is very time consuming and expensive. Therefore priorities have to be set. In Hawaii (Tunison and Stone 1992, cited in Goodland *et al.* 1998) and Galapagos (Macdonald *et al.* 1988, cited in Goodland *et al.* 1998), specifically targeted areas have been chosen where biodiversity is especially high and the control of weeds is effective. Similarly, in Seychelles control efforts have been focused on lowland forests and sites in the national parks. In the UNESCO (United Nations Educational, Scientific and Cultural Organization) biosphere reserve of Vallée de Mai for instance, *Epipremnum* sp. has been successfully controlled, even if not yet completely eradicated, from the *coco de mer* (*Lodoicea maldivica*) forest. The initiative began in 1997 and by 2002 the need for mechanical control was greatly reduced.

It has been suggested that priority should be given to glacis (Biedinger and Fleischmann 2000), where control measures are easier and endemism is high, and to small islands, where complete eradication is often feasible (G. Rocamora, personal communication). An additional argument for priority management on glacis might be that the fecundity of most trees is markedly higher in open areas. There is probably a source–sink movement of propagules from open areas such as glacis, roadsides and open secondary habitats to the closed forest, for both native and exotic species (C. Kueffer, personal observation). Invasive species management on inselbergs could have a significant effect on propagule pressure of native and exotic species on a landscape scale, and thus facilitate habitat restoration in closed canopy habitats.

Outside targeted areas of high biodiversity, it might be appropriate to control the spread of newly introduced species at an early stage. In Seychelles, the Forestry Section of the Ministry of Environment is engaged in the mechanical control of *Clidemia hirta* on Mahé. *Clidemia hirta* is mechanically removed regularly by the rangers in the Morne Seychellois National Park, as well as by forestry workers in plantations. In January 2003, activities involving schools and local communities were planned (M. Vielle, personal communication). *Paraserianthes falcataria* has been targeted by girdling or stripping off the bark on the lower parts of the stem (ring barking) (Wiederkehr and Anderegg 2001). However, there are problems with this control measure, as prior to dying trees produce abundant seed and falling dead trees create gaps easily invaded by light-demanding exotic species.

Clearing heavily invaded secondary forests has been given a lower priority because the costs of clearance and follow-up management can be high with little overall impact on the rate of spread. There are two exceptions to this rule:

- When the value of the exotic species is greater than the cost of harvesting it;
- When delaying removal would substantially increase the cost (Goodland *et al.* 1998).

In Seychelles, the revival of economic timber tree exploitation as well as economic cinnamon exploitation have been suggested as means of controlling exotic timber trees (see Section 7.1. Case Study: *Cinnamomum verum,* and Section 7.2. Case Study: Timber tree species in Seychelles).

To what extent large patches of invasive creepers should be controlled outside sensitive areas to reduce propagule pressure and spreading rates remains an open question.

4.2. Restoration activities

Removal of exotic species from heavily invaded sites needs follow-up activities to restore the habitat, because of the risk of either reinvasion by exotic species or erosion. In Seychelles, habitat restoration after removal of exotic species has been undertaken in lowland forests and in higher altitude forest above 400 m asl (see Box 5: Habitat restoration in the Morne Seychellois National Park).

Lowland forest restoration has mainly been carried out to improve habitats for rare endemic birds. It included removal of relict *Cocos nucifera* plantations and subsequent planting of indigenous coastal plant species such as *Terminalia catappa, Premna oppositifolia, Pisonia grandis, Barringtonia racemosa* and *Heritiera littoralis*. Major restoration projects have been conducted on the islands of Frégate, Cousin, Aride, Conception and Denis. On North, a nursery with 90 endemic species has been in existence for about a year, and 25 000 saplings of 20 species have already been transplanted. On Silhouette, some hectares of lowland forest cleared of creepers and *Clidemia hirta* with public participation have been restored by replanting mainly with endemic palms.

In lowland forests, success has been considerable because indigenous coastal trees grow fast and easily. On Denis, 35 ha of relict *Cocos nucifera* plantation were removed within six months by six people. Reforestation was begun shortly before the rainy seasons using about 3 000 saplings raised in a nursery on the island. Although the forest will take 20 years to regenerate, birds could be reintroduced after only three years. This is partly because considerable numbers of adult indigenous trees are still present. Remnants of indigenous forest facilitate the restoration, and increase the chance of the restoration of the invertebrate fauna. Cousin was restored from a *C. nucifera* plantation within 30 years, almost solely by removing seedlings and promoting natural regrowth. Vigorous regrowth of native trees after removal of *C. nucifera* seedlings has also been observed on Conception. Planting of endemic species also took place on the coasts of the granitic islands to prevent colonization by exotic species after the massive death of *Calophyllum inophyllum* following attack by a fungus (*Fusarium oxysporum*) in the 1990s.

The Forestry Section of the Ministry of Environment cleared 26.4 ha of forest gaps heavily invaded by exotic creepers between 1999 and 2001 (M. Vielle, personal communication). The eradication was carried out at ten different sites from lowland forest (Cap Ternay) to intermediate-altitude forest at an altitude of 400 m asl (L'Exile). Eradication was contracted out on nine sites and one site was eradicated by the Forestry Section. The cost per hectare for the Forestry Section site was between US$1 200 and $1 500. A total of 2.8 ha at Cap Ternay and 2 ha at L'Exile was replanted with mixed stands of endemic palms in December 2002 and January 2003, respectively. The sites were not replanted immediately after eradication, yet a delay of only six months meant that creepers had already reinvaded the site as more light favoured the immediate germination of exotic species from the seed bank. The eradication had to be partially repeated with a concomitant and dramatic increase in costs.

The cost of producing and planting was estimated at SR10 (~US$2) for an endemic palm, and around SR15 (~$3) for a broadleaved tree sapling. On the whole, the cost of the restoration per hectare in lowland forests and accessible intermediate-altitude forests amounts to US$16 500, where replanting consists of endemic broadleaved trees planted at 1 000 trees per hectare. In upland forests, this cost can be tripled (see Box 5).

BOX 5: HABITAT RESTORATION IN THE MORNE SEYCHELLOIS NATIONAL PARK
By Frauke Dogley, Plant Conservation Action Group

In 1996, several projects were started by the Forestry Section of the Ministry of Environment to restore and manage habitats by removing invasive woody plants such as *Cinnamomum verum, Chrysobalanus icaco* and *Syzygium jambos*. Clearing both with and without follow-up replanting of native species have been assessed.

An area of 5 ha was cleared without follow-up replanting at L'Exile, a site where invasive species had overgrown glacis vegetation under very harsh climatic and poor soil conditions. An impact was made relatively quickly because the remaining native vegetation was substantial, but funding of the project ceased and work had to be stopped.

For follow-up replanting, successful propagation techniques had first to be developed. Some of these techniques vary considerably from traditional forestry methods. Areas of 0.75 ha at 430 and 450 m asl and 1.5 ha at 450 to 480 m asl were chosen for replanting with endemic species. A total of 1 280 endemic plants was planted, ranging from species listed as critically endangered, such as *Gastonia lionnetii* and *Vateriopsis seychellarum*, to unthreatened species such as *Phoenicophorium borsigianum*. Different growth rates in different areas indicate that the selection of species needs a good understanding of the site; soil and climatic conditions such as rainfall, in particular, need to be assessed prior to selecting species for reintroduction. Three different types of plant material were used. Healthy palm seedlings growing too close to a path or in too a high density in the forest were collected, and these were replanted as bare rooted palms. In addition, palms cultivated in a nursery either in undersized pots or with fully established root systems were also used.

Four years of monitoring showed that the palms replanted with a fully developed root system had a 1.5–2.5 times higher growth rate than the bare rooted palms. In addition to the soil, the light climate played a crucial role. The slow-growing endemic tree *Vateriopsis seychellarum* was reintroduced under an exotic canopy of *Cinnamomum verum* after the removal of the exotic understorey at one site, and in a second completely cleared site. The growth rate of the plants under the exotic canopy was 2.5 times higher than the growth rate of those in the completely cleared site. In general, growth rates of endemic species are up to ten times slower than those of invasive species.

In upland forests, the habitat restoration cost involving complete removal of exotic vegetation and reintroduction of endemic species (excluding propagation costs) amounts to SR250 000 (i.e. ~US$50 000) per hectare. Of this, SR 150 000 represents labour costs (J. Barreau, personal communication). It is estimated that the Forestry Section could restore about 1–5 ha/year including the necessary follow-up work.

Some lessons learned

- Protecting habitats by designating them as protected areas is not sufficient. The major threat to island habitats is from invasive species. Effective protection requires habitat management.
- A comprehensive assessment of the site is needed prior to restoration work. Following this, the species to be used for restoration can be selected.
- If the exotic canopy is totally removed, endemic species grow more slowly. It is therefore recommended that 'nurse species' be used. The endemic palm *Phoenicophorium borsigianum* has potential as a nurse species. An alternative is to remove the exotic canopy (e.g. *Cinnamomum verum)* in phases while the new vegetation is establishing.
- Replanting schemes must be started without delay after the removal of the invasive species to minimize the impact of invasive species regrowth.
- Best practice is to remove exotic species during the dry season when growth rates are lower and to plan the replanting for the subsequent rainy season. This will reduce restoration costs considerably since maintenance efforts can be reduced.

BOX 5 (CONT.): HABITAT RESTORATION IN THE MORNE SEYCHELLOIS NATIONAL PARK

- Coordination between plant propagation and reintroduction is crucial to avoid high nursery costs and to achieve best success rates in reintroduction schemes. Older seedlings (> 1 year old) have difficulties in adapting and it has been observed that their growth rate is 1.5 times less than younger plants.
- It is estimated that the cost of restoring upland habitats (over 400 m asl) can be up to three times higher than for coastal habitats because of the inaccessibility of sites and the lower growth rates of the replanted species.
- To reduce restoration costs, especially of upland habitats where transport distances are considerable, direct sowing of seeds should be practised.
- As a general rule, upland restoration work involving total clearing and replanting demand the following time allocation: 37 percent for preparation of the site, 30 percent for transportation of plants, 12 percent for digging planting holes and 21 percent for distribution of plants and planting.
- Habitat restoration requires long-term commitment by both the funding agency and the executing agency.

5. AWARENESS AND CONFLICTS OF INTEREST

This section covers awareness and contingent valuation of the invasive species problem by stakeholders and the wider public, and attempts to increase awareness through education. It also deals with potential conflicts of interest.

The great abundance of exotic species in the country has long been acknowledged in Seychelles. Nonetheless, for most of the past century exotic species such as *Cinnamomum verum* and introduced timber trees were positively valued for their economic products and, following the dramatic deforestation that took place in the nineteenth century, for erosion control and the protection of water catchments. A White Paper published in 1971 by the Seychelles Government stated: “In Seychelles forest trees have special value because of the part they play in conserving water and in preventing soil erosion, in addition to their economic value in relation to production forestry. It should not be overlooked that one of the primary objectives of creating timber tree plantations was to provide forest cover, where none existed, in the principal water catchment areas of Mahé, notably Le Niol, Sans Souci, and Grande Anse” (Seychelles Government 1971). The late 1960s and early 1970s marked the beginning of institutionalized nature conservation in Seychelles. Based on the work of Swabey (1961), Jeffrey (1962) and Procter (1970), terrestrial national parks were designated on Mahé and Praslin (Swabey 1970; Stoddart 1984b). Aldabra and the Vallée de Mai were declared World Heritage Sites by UNESCO in 1982 and 1983, respectively. The first attempts to eradicate *C. verum* for conservation reasons were made in the early 1970s (L. Chong Seng, personal communication).

The topic of exotic plant species as a major concern for conservation was not addressed in published notes, scientific articles, newspaper or projects until the beginning of the 1990s (see, for instance, Gerlach 1993b; Friedmann 1994; Gerlach 1996c; Fleischmann 1997). In the second half of the 1990s, the Forestry Section of the Ministry of Environment started several projects on invasive species (see Box 5: Habitat restoration in the Morne Seychellois National Park and Section 7.1. Case Study: *Cinnamomum verum*). During the same period, several private initiatives led to small-scale eradication projects being started.

The wider public is aware of the problem of invasive creepers and *Paraserianthes falcataria*. Both types of invasion have a conspicuous impact on the landscape. In both cases, the government is expected to provide a solution. Assumption of personal responsibility, for example by ceasing the planting of exotic ornamentals or fruit trees, or by eradicating exotic creepers, is infrequent. The public is largely unaware of other invasive plant species. The fact that most Seychellois cannot distinguish or identify exotic and native species properly is a major obstacle for invasion management. In general, awareness of the exceptional natural heritage in Seychelles is high. However, knowledge is restricted to flagship species such as the coco de mer (*Lodoicea maldivica*) and the giant tortoise (*Dipsochelys elephantina*), and famous sites such as the Vallée de Mai and Aldabra. Seychelles has a long history of exploitation of naturally growing, unmanaged resources. The forests are still seen as a free supplier of products such as palm leaves, fruit, fruit bats and medicinal plant material.

In contrast, directly involved stakeholders such as governmental agencies and NGOs are familiar with the problem of invasive species. The Forestry Section of the Ministry of Environment is in a state of transition, as it moves its main focus from wood production to nature conservation and ecotourism. Although eradication of *Cinnamomum verum* had no support among forestry workers in the 1970s (L. Chong Seng, personal communication), measures against invasive species are widely accepted today. However, many foresters stress that the problem of invasive species is associated with the fact that exploitation of forestry products stopped. According to them, the exotic species posed no problem as long as they were managed. Only exotic species that have no positive (economic) value are counted as invasive.

Some private hotels are actively planting and restoring native vegetation. Gardens and public spaces are, however, mainly planted with pantropical ornamentals. Within the Plant Protection Unit of the previously Ministry of Agriculture and Marine Resources (now Ministry of Environment and Natural Resources), which implements the existing law regarding the protection/destruction of woody plant species (see Section 6. Legislative framework to control invasive woody plant species), the awareness of the threat of invasion by new woody plant species is high but the means of action are low.

The Ministry of Education published a series of three educational booklets on native plants of Seychelles in 2000 (Beaver 2000). Earlier, a book had been published on coastal plants and habitats (Beaver 1995). None of these booklets is easily available. A widely sold colour book on the Seychelles flora covers mainly exotic ornamentals (Skerrett and Skerrett 1991). The Ministry of Environment published a poster and a leaflet on invasive creepers in 2000. An information campaign on *Clidemia hirta* started in January 2003. An information leaflet was produced and distributed to the public (M. Vielle, personal communication). In the Vallée de Mai, as well as in other heritage/conservation sites, school classes and wildlife clubs have been involved in the removal of exotic species.

Conflicts of interest are minor. Timber tree and cinnamon exploitation are only small economic activities nowadays. Unresolved conflicts concern the planting of potentially invasive ornamentals in gardens and public spaces, and the planting of exotic species for erosion control, mainly on Praslin. However, if the issue of invasive fruit trees such as *Psidium cattleianum* were to be raised, opposition from the public could be expected, although the debate would be far less intense than in other small island coutries and territories of Western Indian Ocean region, because *P. cattleianum* fruit are not highly prized in Seychelles.

6. LEGISLATIVE FRAMEWORK TO CONTROL INVASIVE WOODY PLANT SPECIES

There is no literature on this issue apart from the existing articles of law. The information given below is based on discussions that took place during this study.

6.1. Inadequate legal control

There is no law in Seychelles that deals explicitly with the management and control of invasive woody plant species, whether at the entry points to the country, or once the plant speices have established. Neither is there any regulation of the movement of invasive woody plant species between national islands. The National Park and Nature Conservancy Act and the Forest Reserves Act ensure the protection of areas of interest for nature conservation and forest resources, but do not provide for any regulation of invasive plant species. Only the Breadfruit and Other Trees (Protection) Act and the Plant Protection Act relate indirectly to the issue.

The Breadfruit and Other Trees (Protection) Act provides a list of woody plant species that are protected by the law. Permission from the Ministry of Agriculture and Marine Resources is needed to fell these species. The act refers mostly to important timber tree species. However, among the 30 protected species, ten are widely acknowledged as invasive: *Cocos nucifera*, *Paraserianthes falcataria*, *Alstonia macrophylla*, *Tabebuia pallida*, *Casuarina equisetifolia*, *Sandoricum koetjape*, *Adenanthera pavonina* and, to a lesser extent, *Eucalyptus* spp., *Artocarpus altilis* and *Artocarpus heterophyllus*.

The Plant Protection Act makes provision for preventing the importation and spread of plant pests and diseases. A phytosanitary certificate issued by the country of origin is obligatory prior to any import of plant material into Seychelles. Agricultural officers are entitled to search and destroy without warrant plant materials imported in contravention of the act and send to quarantine any diseased plant material. The act provides a list of pest species that are barred from entry into the country. By notice in the Government Gazette, the minister may add “any form of plant or animal life or pathogenic agent” to the existing list of pests. In the event of a pest outbreak in the country, containment is dealt with under the law in a number of ways, including the interdiction of movement of the pest between infested and other islands. However, no woody plant species are currently on the list of pests.

Regarding the legislative framework, two approaches for incorporating invasive species can be envisaged, depending on whether the current legislation is amended, or repealed and replaced.

If the current acts are not repealed, provision should be made for:

- A revision of the list of plant species protected by the Breadfruit and Other Trees (Protection) Act. The ten invasive plant species protected should be withdrawn. A clause should be inserted in the act to facilitate their rational felling, with the aim of preventing the opening of wide gaps that would favour invasive species.

- A revision of the Plant Protection Act, adding specific articles on invasive plant species, eventually leading to a list of invasive plant species barred from import, effective quarantine measures, and control to avoid the spread of declared invasive newcomers from infested islands to others.

The revision of the legislation could be modelled on the 'white list' approach of Australia and New Zealand, where all plant species are barred from importation unless they have been shown to be safe.

If the current acts are repealed, provision should be made for:

- Merging the acts into a specific act, in line with Article 8 of the Convention on Biological Diversity, which calls for signatories to "develop necessary legislation for the protection of threatened species and populations".

Consideration has been given in Seychelles to creating a Biodiversity Protection Act, encompassing the issue of invasive woody plant species and repealing most of the current national legislation apart from the Plant Protection Act. The latest draft, dated October 2002, provides for a rather extensive list of woody plant species to be considered as invasive and not to be protected. It also takes into consideration the necessity of protecting habitats from invasion by exotic plant spcies. However, the proposed revision of the existing legislation is still under a 'drafting instructions' format, and there is no official timeframe for the new legislation and related regulations.

Moreover, no revision of the Plant Protection Act is expected in the near future, although in its present form it does not provide for appropriate border control of potentially invasive species.

6.2. Weak capacity for border control

Most exotic plant species are introduced to Seychelles through the official points of entry, either by individuals or in shipments. Most shipments of living plant material are sent to Seychelles by air as they would not survive the sea voyage (W. Dogley, personal communication). The international airport is also the main entry point for individuals entering Seychelles. The border control activities of the Plant Protection Unit of the Ministry of Environment and Natural Resources (previously Ministry of Agriculture and Marine Resources) are concentrated mainly at the airport.

The provisions of the Plant Protection Act are not applied thoroughly.

- With respect to individuals entering the country, customs are responsible for the interception of any illegal material at the international airport. In the case of plant material, responsibility is devolved, on an *ad hoc* basis, to an inspector from the Plant Protection Unit. In practice, customs do not attach much importance to the issue of illegal importation of plant species. They often let individuals through without phytosanitary certificates, and often do not seek advice from the Plant Protection Unit inspectors. It is estimated that less than 25 percent of the luggage at the international airport is screened.

- With respect to shipments entering the country, the Plant Protection Unit inspectors check cargo manifests, but it is estimated that their knowledge of invasive woody plant species is not sufficient to provide effective screening.
- There is no quarantine facility at the airport as prescribed by the law. Suspect materials are brought into the capital, Victoria, where they are kept in an ordinary greenhouse, thereby increasing the risk of spread.
- Resources are scarce: the staff of the Plant Protection Unit responsible for implementing the law amounts to three inspectors and two aids, which is insufficient for efficient shifts at the airport to be organized.
- Given the lack of resources and the fact that living plant material usually comes into the country by air, little control of the possible importation of exotic plant species through harbours is effected. The transport of plant material on boats faring between Seychelles and other small island countries and territories of the Indian Ocean and between its own national islands is not regulated.

6.3. Absence of proper policy planning

Effective control of the spread of invasive species already present on certain islands in Seychelles can only be achieved through appropriate policy planning regarding invasive plant species. At the moment, conservation stakeholders in Seychelles do not have a clear idea about what policy framework to develop, although they all agree that one is needed. For instance, one island of granitic Seychelles (Silhouette) experienced the spread of a well-known invasive tropical shrub (*Clidemia hirta*) at the end of the 1990s. No measures were taken to avoid its human-mediated spread to other islands. *Clidemia hirta* now frequently occurs on Mahé – the neighbouring island to Silhouette – but there has still been no attempt to avoid its further spread to yet more islands of Seychelles.

7. CASE STUDIES

7.1. Case Study: *Cinnamomum verum*

7.1.1. Natural distribution

Cinnamomum verum (syn. *C. zeylanicum*) is the true cinnamon of commerce and belongs to the family Lauraceae, which consists mainly of evergreen trees found in the tropics and subtropics. It is a native of Sri Lanka (Purseglove 1981) and has been reported to invade secondary forests actively in Samoa and on Tutila, American Samoa (HEAR 2002).

7.1.2. Biology of Cinnamomum verum

Cinnamomum verum requires a tropical climate with an annual rainfall between 2 000 and 2 450 mm and no prolonged dry season (Purseglove 1981). It is an evergreen tree of 10–15 m in height with aromatic bark and leaves. The leaves, reddish when young, are stiff and glossy and are up to 17 cm long when mature. The small creamy flowers produce blue or black ovoid fleshy fruits which each contain one seed. The seeds, about 1.5 cm long, are held in a cup-like calyx (Robertson 1989). In good conditions, maturity is reached within three years (D. Doudee, personal communication). The main fruiting season in Seychelles is from February to April. The flowers are probably pollinated by insects, especially flies. *Cinnamomum verum* does not build up a seed bank as viability of ungerminated seeds is quickly reduced, and almost completely lost after 40 days (Kannan and Balakrishnan 1967, cited in Purseglove 1981).

Following its introduction to Seychelles, *C. verum* was first dispersed by endemic frugivores such as the Seychelles blue pigeon (*Alectroenas pulcherrima*) and the Seychelles bulbul (*Hypsipetes crassirostris*). Today the main disperser is probably the introduced Indian mynah (*Acridotheres tristis*) (Lionnet 1976; Stoddart 1984a).

Although soil type has a pronounced effect on the quality of the bark (Purseglove 1981), *C. verum* grows well on most soils of granitic Seychelles. It can be found from the humid mountain forest to the dry glacis habitat with very poorly developed soil.

Cinnamomum verum has been said to exhibit allelopathy. In an unpublished bioassay study with *Leucaena leucocephala* seedlings, growth parameters of above- and below-ground biomass were significantly different between plants watered with cinnamon leaf extract and a control (K. Fleischmann, personal communication). On the other hand, the ecological relevance of bioassay studies for allelopathy is often questioned by plant ecologists.

7.1.3. Introduction to Seychelles

Cinnamomum verum was introduced to Seychelles in 1772 together with other spice plants, and was planted in the Jardin du Roi at Anse Royale on Mahé (Lionnet 1961). Although the garden was destroyed in 1780, *C. verum* had already escaped and colonized forest openings created by clearing for firewood. During the nineteenth century, as the forests of all the granitic islands were cleared for wood, *C. verum* quickly established itself over the whole of Mahé (Stoddart 1984a). It was also used for reforestation on Mahé in 1920, and for that reason it was also introduced to Praslin in the 1930s.

7.1.4. Economic importance

7.1.4.1. History of Seychelles cinnamon industry

Cinnamomum verum has played a very important role in the economic history of Seychelles (Figure 1), not only as a spice crop in the twentieth century but also as a fast-growing species which prevented erosion after the forests had been cleared for wood in the nineteenth century, and thus conserved the water supply of Mahé.

The cinnamon trees on Mahé were believed to be of inferior quality and were consequently not exploited until 1907. By then, samples of bark had shown that it was of the same quality as the trees in Sri Lanka, and small distilleries for producing bark oil began to be built. Cinnamon bark quickly became a major export product and in 1915 distillation had to move over to processing leaf oil as all the larger trees had been cut down (Seychelles Annual Report on Agriculture and Crown Lands 1917). With the beginning of the cinnamon industry, an intensive and extraordinarily rapid destruction of the forests began. *Cinnamomum verum* was felled for its leaves every 18 months and all other remaining woody plants were felled to provide firewood to operate the distilleries. An urgent need for reforestation was noted as early as 1911 (Gibson 1938). As the mountain areas became deforested, the distilleries became concentrated along the coast, where there was abundant coconut trash for fuel (Sauer 1967).

By 1933 there were 82 distilleries working on Mahé, although the number had reduced to about 50 by 1938 (Gibson 1938). With an average annual yield of 13.3 litres of cinnamon leaf oil per hectare (Lionnet 1961), there must have been over 55 km^2 of forest under cultivation when annual leaf oil production peaked at 75 tonnes during the middle of the twentieth century. Given that the total area of Mahé is 142 km^2 (and Silhouette 19.95 km^2) with a forest cover of 90 percent, cropping must have included almost all of the islands' accessible forests (c. 38 percent of total forest cover). As cinnamon bark prices rose in the early 1960s, workers shifted to cropping the bark. Many distilleries could no longer obtain sufficient leaves to keep operating and had to close.

In 1968, the exported tonnage of cinnamon bark reached an all time high of 5 073 tonnes (Purseglove 1981). Since the opening of the International Airport on Mahé in 1971, Seychelles cinnamon industry has slowly declined (Figure 1).

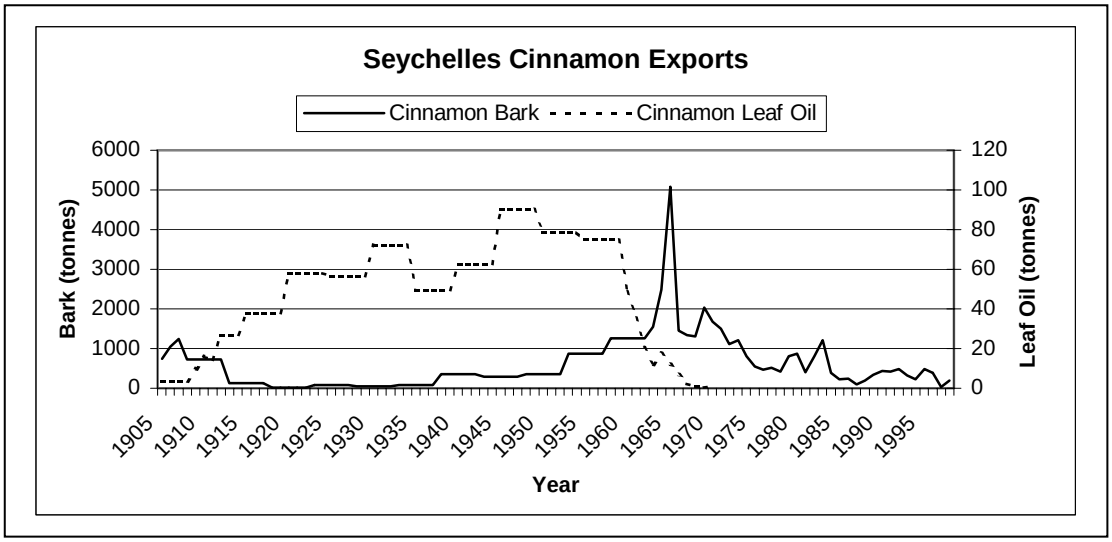

FIGURE 1: SEYCHELLES CINNAMON EXPORTS
Data from: Purseglove (1981); Seychelles Annual Report on Agriculture (1910); Seychelles Annual Report on Agriculture and Crown Lands (1917); Seychelles Information and Statistical Bureau (2002).

7.1.4.2. The Seychelles cinnamon industry today

Cinnamon no longer plays an important part in the Seychelles economy. Small producers collect bark directly from the forests in teams of three to six workers. Collection is done in a destructive manner, harming surrounding endemic species and opening large gaps which are often quickly filled by invasive species. During the last five years (1997 to 2001) production of Seychelles cinnamon bark has reached an average of 260 tonnes, out of which 209 tonnes (i.e. 80 percent) were exported, mainly to Europe, with an average value of SR2.2 million (~US$400 000) compared with a gross domestic product (GDP) of some SR3 300 million (Seychelles Management and Information Systems Division 2002).

7.1.5. Distribution and extent of invasion of **Cinnamomum verum** *in Seychelles today*

Today, *C. verum* is by far the most common tree of the granitic Seychelles, growing from sea level to the highest mountains and in all habitats (Friedmann 1994; Fleischmann 1997). It often dominates intermediate-altitude forests and is one of the few invasive species capable of invading sensitive habitats such as mountain cloud forests and glacis. Although highly abundant on Mahé and Silhouette, it is less common on Praslin and La Digue (Lionnet 1976).

7.1.6. Control of invasions

Eradication of *C. verum* is not an option on the heavily invaded islands (especially Mahé and Silhouette). Control of *C. verum*, even in small areas, is very costly and requires long-term follow-up work.

The Forestry Division, Ministry of Environment, restored forests invaded by *C. verum* in the Morne Seychellois National Park, Mahé (see Box 5: Habitat restoration in the Morne Seychellois National Park).

In 1995, the Indian Ocean Commission funded experiments in the Congo Rouge area of the Morne Seychellois National Park to evaluate possible control methods in this mountain cloud forest. Mechanical methods (uprooting, girdling, replanting) proved inappropriate. Chemical treatment (tree injection) of *C. verum* was very costly (over SR1 per tree). In addition there was damage to the surrounding native flora, probably because of the herbicide being transported through the interlinked root systems of treated and neighbouring trees (J. Barreau, personal communication).

Fleischmann (1999) hypothesized that endemic palms such as *Phoenicophorium borsigianum, Deckenia nobilis* and *Roscheria melanochoetes* act as a regeneration filter affecting the distribution and abundance of *C. verum* seedlings. Unlike *P. borsigianum, C. verum* could not establish and regenerate in very low light levels, which suggests that a dense canopy can prevent invasions by *C. verum* (Fleischmann 1999).

7.1.7. Conclusions

- With a higher growth rate than endemic species, high seed output following a short juvenile period, dispersal of its seeds by birds and high ecological plasticity allowing adaptation to different habitat conditions, *C. verum* has proved to be a very successful invader on the granitic islands of Seychelles.
- Because of the very high abundance of *C. verum* in Seychelles, eradication is not an option.
- *Cinnamomum verum* shaped the economic and cultural history of Seychelles (Zemp 2003). There is potential for the development of ecotourism activities centred on cinnamon. Visits to the former forest cinnamon distilleries could be organized. Participatory activities could be developed with tourists in mind, such as distilling oil and cropping bark and taking it to a drier. In addition, products such as cinnamon bark and powder, essential oil and handicrafts could be manufactured for sale to tourists.
- The demand for cinnamon on the world market has risen above production during the last 20 years as the main exporting countries have slowly moved over to cloves (*Syzygium aromaticum*). With rising demand for biologically produced cinnamon in European countries, cropping wild cinnamon might again become a viable proposition for Seychelles. If this cropping were to be carried out in a sustainable manner, it could become a long-term control management for *C. verum*, generating income and protecting native forests at the same time. A study on the potential for sustainable exploitation as an economical control measure of *C. verum* is currently underway (Zemp 2003).

7.2. Case Study: Timber tree species in Seychelles

7.2.1. Introduction of timber tree species to Seychelles

When humans first landed in Seychelles in the early seventeenth century, the islands were covered in forest. The first visitors described giant trees and impenetrable jungles (Procter 1970). Beginning with the first settlements in 1770 and until the end of the nineteenth century, felling wild timber trees was one of the main industries (Gibson 1938). Wood was a convenient export, both as raw material for the building industry and for shipbuilding. Ships of up to 400 tonnes were built in Seychelles until 1850 and sold to Mauritius, Australia and New Zealand (Pridham 1846; Procter 1970).

As the forests were depleted of their timber trees, faster growing exotic species filled in gaps left by slow growing endemic species.

- In the nineteenth century, *Pterocarpus indicus*, *Adenanthera pavonina*, *Artocarpus altilis* and *Artocarpus heterophyllus*, (used for both food and wood) were successfully planted. In 1875, it was noted that *Adenanthera pavonina* and *P. indicus* were already naturalized and formed important elements of the secondary vegetation (Sauer 1967).

- In the twentieth century, reforestation attempts brought in a great number of species with the aim of growing them for wood for fuel other purposes (building, timber …). *Paraserianthes falcataria* was planted widely from 1911 onwards, at the time more because of its capacity for improving poor soils than for its quality as a timber tree. *Eucalyptus* sp. and *Tabebuia pallida* were widely planted from the 1920s onwards, and *Sandoricum koetjape* and *Swietenia macrophylla* in the 1950s. In 1971, reforestation schemes still favoured the planting of *Paraserianthes falcataria,* which was believed to enrich and stabilize the soil.
- *Casuarina equisetifolia* has been widely planted on coasts and outer islands ever since human settlement first began. Malavois reported the presence of the tree on the shores of the granitic islands as early as 1787. It is still being planted nowadays to stabilize and 'green' reclaimed land, for instance on Mahé.

Nowadays, *Paraserianthes falcataria, Tabebuia pallida*, *Casuarina equisetifolia* and *Adenanthera pavonina* are among the main invasive woody plant species in Seychelles.

7.2.2. Economic importance

Compared to the rest of the world, the production costs for forest plantations in Seychelles are high because the small scale of the operations and the rugged topography result in high management, logging and conversion costs (M. Vielle, personal communication). Nowadays, the forestry sector contributes just 0.4 percent of the GNP. Wood and wood products supplied to the domestic market meet less than 25 percent of the national requirements per year (INDUFOR 1993). Timber trees are no longer harvested on a regular basis outside forest plantations, a change which might have facilitated the further spread of invasive timber tree species. However, local wood has potential as it is of higher quality than imported wood (usually *Pinus* spp.) if processed appropriately. Reviving the exploitation of local invasive timber tree species could contribute to the control of their populations.

TABLE 7: MAIN FORESTRY PLANTING SCHEMES IN SEYCHELLES SINCE 1883[a]

Period	Area replanted	Main species	Comments
1883–1909	Unknown	*Tectona grandis*, *Calophyllum inophyllum*	Insufficient growth rates and yield
1909–1920	35–55 ha	*Casuarina equisetifolia* (5.2 ha), *Tabebuia pallida* (4.4 ha), *Paraserianthes falcataria* (1.75 ha), *Adenanthera pavonina* (1.5 ha), *Pterocarpus indicus* (0.65 ha)	All successful
1920s–30s	Unknown	*Paraserianthes falcataria*, *Tabebuia pallida*, *Adenanthera pavonina*, *Casuarina equisetifolia*, *Sandoricum koetjape*	Emergence experiences: *P. falcataria* on sites adjacent to rivers and streams; *T. pallida* and *A. pavonina* on poorer sites on ridges and precipitous grounds; *C. equisetifolia* on coasts; *S. koetjape* on better sites in valley bottoms
	95.3 ha on Mahé, 8.1 ha on Praslin (100,000 seedlings)	*Eucalyptus* sp.	1935, Colonial Development Welfare Scheme, colonial interest in Eucalyptus oil production and wood. *Eucalyptus* sp. not successful (poor growth, high mortality)
1940s–1950s	Unknown	*Swietenia macrophylla*	1952, first trials
1952–1971	1091 ha on Mahé (ceased 1964), 306 ha on Praslin (mainly before 1968)	*Swietenia macrophylla* and species listed above, with same pattern as in former periods	Active planting. In 1968–1971 only 6.5 ha/year planted
1970s on	10–20 ha in 1980s, 20 ha in 1992, 10 ha/year in 1993–96; no substantial replanting since 1996	Mainly *Swietenia macrophylla* (others, i.e. *Eucalyptus camaldulensis*, *Sandoricum koetjape*, *Pterocarpus indicus* and *Tabebuia pallida*, had minor share of planting, discontinued in 1988)	Development of tourism and lessening interest in forest production. 1980s replanting target of 100 ha/year not reached. Plantations covered 520 ha in 1996; 300 ha (57%) *Swietenia macrophylla*
2002		Replanting scheme for *Swietenia macrophylla* under discussion, no clear timeframe	Current main criterion for planting: insufficient/lack of forest cover through forest fire/exploitation. Forest exploitation usually based on selective cutting followed by enrichment planting

[a] From Henry (1976), INDUFOR (1993), Forestry Section records and M. Vielle (personal communication).

7.2.3. Timber tree species

Table 7 gives an overview of the planting schemes during the twentieth century. The main invasive timber tree species today are often those that showed signs of being well adapted to Seychelles conditions early on, and were consequently widely planted. The principal species in this context are *Paraserianthes falcataria, Adenanthera pavonina, Tabebuia pallida, Casuarina equisetifolia, Sandoricum koetjape* and, to a lesser extent in terms of invasion, *Swietenia macrophylla*. These species offered complementary characteristics for the rapid restoration of various types of site denuded by former logging activities. For example, *Paraserianthes falcataria* was suitable for sites adjacent to rivers and streams, *Sandoricum koetjape* in better sites with deeper soils in valley bottoms, *Tabebuia pallida* and *Adenanthera pavonina* on poorer sites on ridges and precipitous grounds, and *Casuarina equisetifolia* on coasts. However, the wood qualities of these species varied, the lowest quality wood coming from *Paraserianthes falcataria*.

Apart from these main species, 95 woody plant species previously introduced to Seychelles for reforestation purposes, but whose cultivation was discontinued, have been proposed recently to have potential for the wood industry (Delotter 2001). Among these are both apparently non-invasive species, and very highly invasive species such as *Alstonia macrophylla*.

Cocos nucifera was widely planted during the nineteenth century on the plateaux of inner islands and on outer islands, where it is now considered as invasive. It was not planted for wood but as a food resource and for copra production. However, today it is used principally for the production of handicrafts.

7.2.4. Control measures

7.2.4.1. Mechanical control

The only extensive attempts in Seychelles were:

- The ring barking of 2 000 *Paraserianthes falcataria* on Mahé in the 1990s (see Section 4.1. Control measures in Seychelles);
- The efficient control of *Cocos nucifera* populations in some coastal restoration projects (see Section 4.1.). However, attempts remain scarce as the laws of Seychelles still officially protect *C. nucifera* (see Section 6.1. Inadequate control by the law).

7.2.4.2. Control measures through the use of wood

Controlling populations of invasive timber tree species is most efficient when their wood is used economically.

TABLE 8: PRICE LIST OF WOOD [a]
(Forestry Section 2002)

Species name	Vernacular name	Market price (US$/m^3)
Adenanthera pavonina	**Agati**	**91**
Albizia lebbeck	**Bois noir**	**200**
Artocarpus altilis	**Fruit à pain**	**91**
Artocarpus heterophyllus	**Jacquier**	**125**
Calophyllum inophyllum	Takamaka	125
Casuarina equisetifolia	**Casuarina**	**91**
Hernandia nymphaeifolia	Bois blanc	91
Mimusops sechellarum	Bois de natte	200
Paraserianthes falcataria	**Albizia**	**19**
Pterocarpus indicus	**Sandragon**	**200**
Sandoricum koetjape	**Santol**	**91**
Swietenia macrophylla	**Acajou**	**200**
Tabebuia pallida	**Calice du pape**	**94**
Terminalia catappa	Badamier	91

[a] Information on exotic species is in bold.

The main species introduced as timber trees are still sold today (see Table 8). However there are discrepancies between species. *Pterocarpus indicus* and *Swietenia macrophylla* are sold successfully at US$200/m^3, whereas the market for *Paraserianthes falcataria* wood is too small to clear the available supply, even at $19/m^3. It has been hypothesized that populations of *Pterocarpus indicus* and *Swietenia macrophylla* are controlled through its exploitation, while those of *Paraserianthes falcataria* continue to expand because the wood is not being used.

Generally, locally produced wood is considered as heavy, difficult to work and more expensive than imported pine from South Africa. The image of locally produced wood needs raising to attract more customers. Indeed, it seems that *Paraserianthes falcataria* could competitively be used as plywood by the local building and furniture industries. *Cocos nucifera* could be used for building and for wood carving (Delotter 2001).

More research is needed on the potential of local species for the wood industry. Hardwoods could, for instance, be used to produce wooden floors (Delotter 2001). The Ministry of Industries and International Business has designed a database of 100 species that could be evaluated for the potential of their woods. It has recently employed a technical assistant to focus on this matter.

7.2.5. What should be done next?

In addition to researching the potential of the wood of various species, future support to the local wood industry could be achieved by:

- Raising public awareness of local wood production, and its potential and qualities compared with imported woods;

- Improving the local sawmilling capacity by introducing new equipment and better training in order to offer products of quality at a competitive price;
- Supporting the development of the handicraft sector to serve the demanding tourist industry.

8. CONCLUSIONS AND RECOMMENDATIONS

8.1. Conclusions

- Out of the 230 dicotyledonous woody plant species introduced to Seychelles, some 22 or approximately ten percent have become invasive. As a general rule about one percent of the species introduced to a country become invasive (Williamson 1996). The proportion of exotic woody plant species that have become invasive in Seychelles is therefore apparently very high.
- Out of the some 35 monocotyledonous woody plant species introduced to Seychelles, none is apparently invasive. This may be because endemic palms and pandans are the most widespread remaining native species, and endemism among monocotyledonous woody plant species is very high, and thus there may have been no niches available for exotic palms and pandans to exploit.

8.1.1. Degree of invasion

8.1.1.1. Granitic islands

- Of the total woody plant species present on the granitic islands, about three-quarters are exotic. Nowadays, 13 of them are considered as highly invasive (*Cinnamomum verum, Paraserianthes falcataria, Psidium cattleianum, Syzygium jambos, Casuarina equisetifolia, Alstonia macrophylla, Chrysobalanus icaco, Leucaena leucocephala, Cocos nucifera, Adenanthera pavonina*[1]*, Tabebuia pallida, Lantana camara* and *Carica papaya).* All of these are frequently invasive elsewhere in the tropics, except *Cinnamomum verum* and *Alstonia macrophylla*.
- Most of the invasive woody plant species were introduced at least 90 years ago. They naturalized and spread when Seychelles became extensively deforested.
- Some exotic species are currently seen to be expanding their range on the granitic islands: *Ardisia crenata, Ardisia elliptica, Clidemia hirta, Dillenia suffruticosa* and *Memecylon caeruleum*.
- Identifying potentially new invasive species has proved difficult, apart from *Spathodea campanulata*, which has been identified as invasive elsewhere in the tropics (Binggeli *et al*. 1998).
- On granitic islands, the least invaded habitat is glacis, followed by high-altitude forests.

[1] Not considered unequivocally as introduced

- Woody plant species are the most problematic environmental weeds. Nonetheless, creepers, which have been a major concern as agricultural weeds for the last 20 years, are now showing a tendency to become problematic in natural habitats.

8.1.1.2. Coralline and limestone islands

- The percentage of introduced species among species restricted to the limestone islands is 17 percent, among those restricted to the coralline islands 92 percent, and among those present on both types of islands 63 percent.
- The main invasive problems stem from non-woody plant species: *Agave sisalana*, *Senna occidentalis*, *Stachytarpheta jamaicensis* and *Turnera angustifolia*.
- The most problematic woody plant species are the trees *Casuarina equisetifolia* and *Cocos nucifera* and the shrubs *Carica papaya*, *Lantana camara*, *Leucaena leucocephala* and *Ricinus communis*.

8.1.2. Environmental and economic impacts

- Knowledge about the environmental and economic impacts of invasive species in Seychelles is anecdotal and has never been quantitatively described.
- The only species known to have an impact on ecosystem processes is *Paraserianthes falcataria*, which apparently changes soil and light conditions in the forest.
- The biggest concern is consensually recognized to be the threat to native biodiversity.

8.1.3. Control measures and habitat restoration

- Most control attempts in Seychelles involved early detection and mechanical control of small expanding populations, in conjunction with habitat restoration projects in both lowland and upland forests.
- Habitat restoration has proved fast and easy in coastal habitats where probably up to 100 ha/year could be restored. Restoration is much more expensive and slower in higher altitude forests.
- Conditions for successful of habitat restoration in Seychelles are (i) small-scale initiatives, (ii) an ‘integrated’ approach that includes both botanists and zoologists, (iii) commitment of the wider public, (iv) long-term commitment, and (v) mechanical control.

8.1.4. Awareness

- Seychelles conservation community has been aware of the threat of invasive species since as long ago as the 1970s (eradication of *Cinnamomum verum* for conservation purposes), but real concern materialized only in the 1990s.
- Awareness among the wider public remains low. The public is sensitized to the problem of invasive creepers and *Paraserianthes falcataria*, which have a direct impact on the landscape. However, their knowledge of exotic and endemic species remains insufficient.

- The commitment of the wider public is a prerequisite for success of control measures at least on the main granitic islands.

8.1.5. Legislative framework

- The legislative framework to prevent new introductions of potentially invasive woody plant species is not comprehensive and is outdated (Breadfruit and Other Trees Act, Plant Conservation Act).
- Human resources and infrastructure for controlling the introduction of exotic plant species are inadequate.

8.2. Recommendations

8.2.1. Fill knowledge gaps

- Apart from general, well-known characteristics of invasive species such as good dispersal ability, nitrogen-fixing capacity and fast growth, this report cannot provide more detailed conclusions about the characteristics of invasive species in Seychelles. It is strongly recommended that, in cooperation with the other Indian Ocean small island countries and territories, a screening system for potentially new invasive species, similar to the one in South Africa, be developed.
- More studies on forest structure are needed to understand the impacts of invasive species, especially on epiphytes and the invertebrate fauna, (akin to the studies already undertaken for Seychelles birds). This would help to elucidate the effects of invasive woody plants on faunal and epiphytic biodiversity.

8.2.2. Keep on increasing awareness

- A booklet on the main native plant species should be published and made widely available. A series of programmes on national television on native plant species would be another useful education tool.
- A reduction in the planting of exotic ornamentals in public places and around hotels and their replacement by native plants, under the strict supervision of the responsible authorities, should be encouraged.
- Establishment of native medicinal plants by herbalists in private gardens could be promoted. Native plants should become commercially available.
- Fostering personal commitment to and a sense of responsibility for the native flora seems crucial. School classes could, for instance, adopt a small patch of forest to restore and manage under the supervision of the appropriate authorities.

8.2.3. Promote sound habitat restoration

- Nature conservation goes beyond designating protected areas. An active habitat restoration approach is vital for the protection of the native flora.

- Based on experience from pilot projects, restoration work requires strategic land-use planning (at least for the main granitic islands) to define priority areas for restoration. The designation of priority areas should be based on the mapping of core biodiversity zones but should also take into account the broader problem of high propagule pressure.
- A network of all agencies active in restoration work should be established to ensure better sharing of experience and expertise, and to promote better coordination of activities.
- Small-scale integrated projects managed by a well-defined institution that assures long-term commitment are the most promising.
- Sustainable exploitation of timber trees and *Cinnamomum verum* may be a sound strategy to manage pressure for some prominent invasive species outside core biodiversity zones.

8.2.4. Improve legislative framework and reinforce control capacities

- The legislation should be modified to make it comprehensive and up to date.
- Custom services should be sensitized to the threat of invasive plant species and directed to collaborate more closely with the Plant Protection Unit of the Ministry of Agriculture and Marine Resources.
- More and better-trained human resources are a prerequisite for the Plant Protection Unit to be able to fulfil its mission and especially to provide effective border control. Above all, a plant pathologist, an entomologist and a taxonomist are needed.
- An appropriate quarantine facility with a well-equipped greenhouse should be developed at the international airport on Mahé.

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APPENDICES

Appendix 1: list of abbreviations and acronyms

asl	above sea level
ETH	Swiss Federal Institute of Technology
FAO	Food and Agriculture Organization of the United Nations
GDP	gross domestic product
GNP	Gross National Product
ICS	Island Conservation Society
IUCN	World Conservation Union
MOE	Ministry of Environment and Natural Resources
NGO	Non-Governemental Organization
NPTS	Nature Protection Trust of Seychelles (NPTS)
PCA	Plant Conservation Action Group
SIF	Seychelles Island Foundation
UNESCO	United Nations Educational, Scientific and Cultural Organization

Appendix 2: some common names of cited plants

Species name	Common name(s)
Acacia spp.	Acacias, Wattles
Adenanthera pavonina	Agati
Agave sisalana	Sisal
Albizia lebbeck	Bois noir, Siris tree
Aleurites moluccana	Bancoulier
Alstonia macrophylla	Bois jaune
Anacardium occidentale	Cashew
Ananas comosus	Pineapple
Annona squamosa	Sugar apple
Artocarpus altilis	Breadfruit, Fruit à pain
Artocarpus heterophyllus	Jackfruit, Jacquier
Asystasia sp.	Mantzou
Calophyllum inophyllum	Takamaka
Camellia sinensis	Tea
Cananga odorata	Ylang-ylang
Carica papaya	Papaya
Casuarina equisetifolia	Casuarina, Filao
Chrysobalanus icaco	Cocoplum, Icaquier
Cinnamomum verum	Cinnamon
Citrus reticulata	Mandarin
Citrus spp.	Citrus
Cocos nucifera	Coconut
Coffea canephora	Robusta coffee
Coffea spp.	Coffee
Cola nitida	Kola
Cryptomeria japonica	Japanese (red) cedar
Dicranopteris linearis	Bracken fern
Eichhornia crassipes	Water hyacinth
Elaeis guineensis	Oil palm
Elettaria cardamomum	Cardamon
Eucalyptus spp.	Eucalypts
Gossypium spp.	Cotton
Hernandia nymphaeifolia	Bois blanc
Hevea brasiliensis	Rubber, Rubberwood
Lantana camara	Lantana
Lodoicea maldivica	Coco de mer
Mangifera indica	Mango
Melia azedarach (syn. *M. dubia*)	Persian lilac, Margosier, Lilas de Perse
Mimusops sechellarum	Bois de natte
Morinda citrifolia	Bois tortue
Myristica fragrans	Nutmeg
Oryza sativa	Rice
Pandanus spp.	Pandans, Screwpines
Panicum maximum	Guinea grass, Fatak grass
Paraserianthes falcataria	Albizia

Species name	Common name(s)
Passiflora edulis	Passion fruit
Pinus spp.	Pines
Pistia stratiotes	Water lettuce
Pogostemon cablin	Patchouli
Psidium cattleianum	Cherry/Chinese/Strawberry guava, Goyavier,
Psidium guajava	Guava
Pterocarpus indicus	Sandragon
Pueraria phaseoloides	Tropical kudzu
Raphia farinifera	Raffia palm
Ravenala madagascariensis	Traveller's tree
Ricinus communis	Castor
Saccharum officinarum	Sugar cane
Sandoricum koetjape	Santol
Schinus terebinthifolius	False pepper
Spathodea campanulata	Tulip tree, Tulipier du Gabon
Swietenia macrophylla	Broad-leaved mahogany, Acajou
Swietenia mahogani	Small-leaved mahogany, Mahogani
Syzygium aromaticum	Clove
Syzygium jambos	Rose apple, Jambrosa
Tabebuia pallida	Calice du pape, Pink tecoma
Tamarindus indica	Tamarind
Terminalia catappa	Badamier, Tropical almond
Vanilla planifolia	Vanilla