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Forest Health & Biosecurity Working Papers

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

1. Synthesis

By

C. KUEFFER¹, P. VOS², C. LAVERGNE³ and J. MAUREMOOTOO⁴

¹ Geobotanical Institute, ETH (Federal Institute of Technology), Zurich, Switzerland

² Forestry Section, Ministry of Environment & Natural Resources, Seychelles

³ Conservatoire Botanique National de Mascarin, Réunion

⁴ Mauritian Wildlife Foundation, Mauritius

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Comments and feedback are welcome.

For further information please contact:

Pierre Sigaud, Forestry Officer
(Forest Genetic Resources)
Forest Resources Division
Forestry Department
FAO, Viale delle Terme di Caracalla
00100 Rome, Italy
Fax: + 39 06 570 55 137
Email: pierre.sigaud@fao.org

Gillian Allard, Forestry Officer
(Forest Protection)
Forest Resources Division
Forestry Department
FAO, Viale delle Terme di Caracalla
00100 Rome, Italy
Fax: + 39 06 570 55 137
Email: gillian.allard@fao.org

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This paper is one of four studies and a synthesis which were undertaken to review the status of invasive woody species in the Western Indian Ocean. Countries and territories studied include the Comoros archipelago, Mauritius, Réunion and Seychelles. A summary of the regional findings, including methodology, main results and conclusions, is available in the synthesis document:

Kueffer, C., Vos, P., Lavergne, C. and Mauremootoo, J. 2004. *Case Studies on the Status of Invasive Woody Plant Species in the Western Indian Ocean. 1. Synthesis.* Forest Health and Biosecurity Working Papers FBS/4-1E. Forestry Department, Food and Agriculture Organization of the United Nations, Rome, Italy.

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

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1. INTRODUCTION

Within the framework of biosecurity and forestry (Cock 2003), the Forestry Department of the Food and Agriculture Organization of the United Nations (FAO) set up a programme to investigate the invasiveness of forest trees. A global review identified considerable knowledge gaps in little-studied regions (Haysom and Murphy 2003). A set of regional case studies should help to fill these gaps. The first of these regional case studies to be published was for Southern Africa (Nyoka 2003). This report on woody invasive species in the Western Indian Ocean is the second such survey.

The report summarizes the results of a rapid assessment survey on invasive woody plant species in the Western Indian Ocean region commissioned by the Forestry Section of the Seychelles, Ministry of Environment, on behalf of the Forestry Department of FAO. The survey was conducted through a scientific consultancy by the Geobotanical Institute of the Swiss Federal School of Technology (ETH), Zurich, Switzerland, and in collaboration with the Conservatoire Botanique National de Mascarin (Réunion) and the Mauritian Wildlife Foundation (Mauritius). The Service des Eaux et Forêts (Mayotte) and the Centre National de la Recherche Scientifique (the Union of the Comoros) participated actively in the survey in the Comoros archipelago. The study covers the small island countries of the Western Indian Ocean, i.e. the Republic of the Seychelles, the Union of the Comoros and the Republic of Mauritius, together with the French overseas department (*département*) of Réunion and territorial collectivity of Mayotte.

The report is divided into five parts: Part 1 synthesizes the results on a regional scale, while Parts 2–5 present the results for the individual countries and territories in detail. The survey of the Comoros archipelago included the Union of the Comoros and Mayotte, while the Mauritius survey dealt with the country's two main islands, Mauritius and Rodrigues. In Parts 2–5, text boxes present on-going activities by specific agencies in the small islands. These boxes were written by an individual involved, often a member of the executing institution. In addition, case studies are included (except in Mauritius) that summarize the ecology and management of two invasive woody plant species per report. The case studies can be used independently from the main text as a synthesis of current information on these species.

According to the terms of references, this survey had four main objectives:

1. Development of a rapid assessment survey methodology to classify and assess the invasiveness and impact of woody plant species on a regional scale, based on literature surveys and expert interviews (see this Part: Section 2. Methods). The methodology should be made available for application in other regions.
2. Making the knowledge and data on invasive woody plant species in the surveyed small island countries and territories easily accessible (see Parts 2–5). On the one hand, most of the existing knowledge has not been published and is only accessible in grey literature or as tacit expert knowledge. On the other hand, lack of resources means that scientific publications are difficult to obtain in the small islands of the Western Indian Ocean.
3. Assessment of the invasiveness and impact of woody plant species in the region (see this Part: Sections 5–7). The results of this study form part of a global survey of the impact and invasiveness of woody plant species within the framework of biosecurity and forestry.
4. Recommend management strategies for invasive woody plant species on a regional scale (see this Part: particularly Sections 8–10).

An implicit fifth aim was to develop a network of institutions in the region that have an interest in the management of invasive plant species and could collaborate in the future to share their own knowledge on the issue. This aim has been fulfilled as a consequence of the participatory nature of the survey. In October 2003, the network developed further through a workshop hosted by the Seychelles Ministry of Environment in the Seychelles, and organized by the Indian Ocean Commission (IOC) with the technical support of the IUCN (World Conservation Union) Invasive Species and Indian Ocean Plant Specialist Groups (Mauremootoo 2003).

A prerequisite of the study was to clarify the definition of an invasive species:

- *Native* plants are species that are thought not to have been introduced by man to a specified area.
- *Indigenous* is generally used as a synonym for native, except in the Seychelles where indigenous refers specifically to the native species that are not endemic.
- *Endemic* plants are species that are confined to an island, a country or a region (e.g. Seychelles endemic species).
- *Exotic* plants are species that are thought to have been introduced by man. *Alien* and *non-indigenous* are synonymous with exotic.

In the international literature, it is now widely accepted that the term *invasive* refers solely to *exotic* species (see for instance Daehler 2001; Kolar and Lodge 2001). Among the experts in the Western Indian Ocean region there is a general preference to use the term *invasive* only for exotic species, although some will accept its use for native species that become problematic. However, in this study *invasive* refers to exotic species only.

There is still considerable debate in the literature about which other characteristics are obligatory for a species to be designated *invasive*. While some authors stress that a negative environmental or economic impact is an obligatory part of the definition of an *invasive* species (Alpert *et al.* 2000; Davis and Thompson 2000, 2001), others disagree (Daehler 2001). The impact criterion was criticized as normative and unquantifiable (Daehler 2001). Parker *et al.* (1999) made an attempt to develop a framework for quantifying ecological impacts of *invasive* species. In the Western Indian Ocean region, *invasive* species are generally discussed in a management context, implying a negative impact. Some emphasize the aspect of *invasive* species transforming ecosystems, referring to a subset of *invasive* species sometimes called ‘transformer species’ (Richardson *et al.* 2000).

Richardson *et al.* (2000) distinguished between *naturalized* species that regenerate freely, but mainly under their own canopy, and *invasive* species that frequently regenerate in natural or semi-natural vegetation at considerable distance from the parent trees. They suggest the following definition: “Invasion [...] requires that introduced plants produce reproductive offspring in areas distant from sites of introduction (approximate scales: > 100 m over < 50 years for taxa spreading by seeds and other propagules; > 6 m/3 years for taxa spreading by roots, rhizomes, stolons or creeping stems)”. Spread as an obligatory criterion is emphasized by many other authors (e.g. Daehler 2001; Kolar and Lodge 2001). Another approach is to recognize a dichotomy between *established* species (growing outside planted areas but not spreading) and *invasive* species (implying spread) (Kolar and Lodge 2001).

We suggest that the appropriate categorization in a management context is between (apparently) *non-invasive*, *potentially invasive* and *invasive* species. We use the term potentially invasive for species naturalized in an island that are known to be invasive elsewhere in the world, and/or are showing strong tendencies to invade secondary or primary vegetation. We use the term invasive for species that are problematic in both anthropogenic systems (i.e. as weeds) and natural systems. Reference to the classical concept of weediness in anthropogenic systems is especially useful in the context of legislation and awareness building (see this Part: Sections 9–10).

2. METHODS

2.1. Outline of the surveys

The country and territory surveys were conducted using written questionnaires (see Appendix 2 for the Seychelles questionnaire, provided as an example) and a one-week visit to each country or territory when expert interviews were conducted. The same questionnaire was used for all surveys, apart from the specific sections on species and habitats, which were adapted for each country or territory. The questionnaire was sent to identified experts about one month before the visit. Each survey was coordinated and information collated by a local agency (Forestry Section in Seychelles, Conservatoire Botanique National de Mascarin in Réunion, Mauritian Wildlife Foundation in Mauritius, Centre National de la Recherche Scientifique in the Union of the Comoros, Service des Eaux et Forêts in Mayotte). Visits were made to most relevant experts and stakeholders (see the lists of contributors in Parts 2–5; generally these were: the forestry, conservation and quarantine services, the ministry of agriculture, the national park authority, the university and NGOs), apart from horticulturalists and importers of exotic ornamentals. In Seychelles, a one-day workshop was also organized (see Appendix 2, Section F). A draft version of the report was sent to all participants for review.

The study covered aspects of both the biology and the management of invasive woody plant species.

Information on the biology is divided into three parts: invasion history, invasiveness, and invasibility of habitats. This division is in accordance with the growing agreement that three complementary aspects have to be investigated in order to understand invasion processes (Williamson 1996; Lonsdale 1999):

1. Invasiveness, i.e. the characteristics of the species.
2. Invasibility, i.e. the susceptibility of the invaded habitat.
3. Propagule pressure, i.e. the number of propagules present or arriving at a site (cursorily covered in this report, on a landscape scale, in the sections on invasion history in Parts 2–5).

Information on management is divided into four parts: economic and ecological impacts, control measures (mechanical, chemical and biological control) and habitat restoration; awareness and conflicts of interest; and legislation. Aspects of national strategy building and policy are included in the section on awareness, while border control and prevention is included in the section on legislation, and early detection is included in the section on control measures (compare with Wittenberg and Cock 2001).

2.1.1. Discussion of the survey method

- Little literature and few data on the problem of invasive species were available. A few reports were frequently cited and dominated the debate.
- There were fewer than ten experts per country or territory with a broad knowledge about the problem of invasive species. These experts were in regular contact with each other. Thus, data and evaluations from the expert judgments and literature are highly correlated.
- Awareness of the problem emerged very recently. The institutional framework to deal with it is still in a process of formation in all countries and territories. A survey in such a context is very much part of a social process between stakeholders and experts, whereby responsibilities among agencies are defined, and management priorities are set, which involves subjective valuation and stakeholder interests.
- The last two statements (few correlated expert judgments, the dynamic social process) strongly favour an interactive approach such as the workshop organized in Seychelles.
- Close collaboration with a local agency in each country or territory was crucial to the quality of the results of the survey.

2.2. Assessment and classification of woody plant species invasiveness

A primary objective of the survey was the classification of the main invasive woody plant species in the region. In the questionnaire the following categories were used:

- *Main invasive species* (rated as very problematic, problematic or rather problematic);
- *Apparently not invasive species* (with potential for becoming invasive because they are widely planted or are invasive in other tropical countries);
- *Expanding new invasive species* (already established in restricted areas with potential for further spread).

In the survey, a species assigned to the main invasive species category could be accompanied by a comment to justify the rating. The most common criteria given were abundance and negative impact. Other criteria included feasibility of control, invasion of sensitive areas and positive impact (e.g. forestry trees were rated less problematic by forestry workers in Seychelles because of their usefulness). From the responses, it became clear that 10–15 species per country or territory were widely accepted as invasive woody plant species; we present them throughout this report as *main invasive woody plant species*. Among the main invasive species there was a subset that was consistently rated as very problematic. In this report they are subsumed under the category *most problematic invasive woody plant species*. There was an additional set of species that were cited by only some of the experts consulted. Those species are grouped as *non-consensus invasive woody plant species*.

The reasons for including the category for apparently not invasive species were (i) a comparison of invasive and non-invasive exotic species may help improve understanding of invasions (Kolar and Lodge 2001), and (ii) detection at an early stage of establishment is of paramount importance for the effective control of new invasive species (e.g. Wittenberg and Cock 2001).

The inclusion of a category for expanding new invasive species was also intended to help identify potentially new invasive species.

In line with the precautionary principle we decided to include all apparently not invasive species together with expanding new invasive species in the category *potentially new invasive woody plant species*.

The classification used in the Seychelles report (Part 5) differs slightly. As a result of the workshop, some adjustments were made to some categories. Some of the non-consensus species were not rated as invasive by some experts because they have large fruit and thus are spreading only slowly. We decided to present these as *naturalized, regenerating, but slowly spreading woody plant species*. Further, it was agreed that some of the newly spreading species were very problematic. They were taken out of the potentially invasive species category and presented as *expanding woody plant species*. For some apparently not invasive species it seemed safe to present them as such, although obviously this does not mean that they cannot become invasive in the future.

2.2.1. Discussion of the invasiveness classification method

It was not possible, within the scope of this study, to apply a structured, quantitative scheme for the rating of invasive woody plant species. In Réunion two such approaches have been tested in the past. Macdonald *et al.* (1991) used five criteria (abundance, potential extent of invasion, rate of spread, difficulty of control and ecological impact), while Cazanove (1999) used the method developed by Hiebert (1996, 2001) which includes two main axes (impact and feasibility of control). CIRAD (Centre de Coopération Internationale en Recherche Agronomique pour le Développement) in Réunion intends to apply existing invasiveness screening systems from other regions of the Indian Ocean (T. Le Bourgeois, personal communication). A Ph.D. study is currently underway to compare a wide range of biological characteristics of invasive and native woody plant species in Seychelles, with a special emphasis on ecophysiology and the establishment phase (Schumacher *et al.* 2003).

Our classification is based on qualitative contingent expert valuation. The method proved to be able to discern between the most problematic, problematic and less problematic invasive woody plant species, and to provide a list of potentially invasive woody plant species. However, the expert valuations were highly correlated and mainly based on abundance and visible impacts (especially thicket formation).

Further development of a comprehensive invasive woody plant species assessment is necessary in the region. Two complementary paths should be followed: (i) risk assessment of potentially invasive species, including those already established and candidates for introduction, (i.e. a screening system) based on biological characteristics commonly found among invasive woody plant species (see for instance Binggeli 1996; Rejmanek 1996; Richardson 1998; Daehler and Carino 2000; Grotkopp *et al.* 2002; Randall 2002), and (ii) prioritization of the management of already established species based on management costs and feasibility (e.g. abundance, growth rates, seed bank, propagule pressure, feasibility of mechanical/chemical eradication, biological control, site accessibility, conflicts of interest, negative impact of management measures) and negative impact of the species (e.g. invading sensitive areas, risk of further spread, transformer species, outcompeting native species).

2.3. Classification of impacts

In the questionnaire we asked for both negative and positive impacts of invasive species. The positive impacts are presented in each report (Parts 2–5) in the conflicts of interest section, except in the Seychelles report where they are discussed in more detail in a separate section. The negative impacts are subdivided into ecological impacts in natural systems and impacts in anthropogenic systems. Impacts in anthropogenic systems were few and were therefore not further subdivided. Ecological impacts were described under the following three categories, modified from Parker *et al.* (1999):

- Ecosystem impacts (i.e. transformer species' effects on, e.g., the disturbance regime or resource availability);
- Impacts on biological interactions (e.g. competition within a trophic level, interactions with herbivores, frugivores, insectivores, pollinators, pathogens; mutualism among exotic species);
- Genetic effects (especially hybridization).

3. GENERAL BACKGROUND

The environment of the small islands studied in this survey – be it natural or social – varies widely from one island to another. For instance, Réunion covers 2 512 km² whereas the total land mass of the 115 islands forming Seychelles covers 438 km² only. The age of the islands varies from a few thousand years for some coral islets, to 130 000 years for the recently born volcanic Grande Comore, to more than 65 million years in the case of the granitic Seychelles. In terms of climate, Seychelles and the Comoros archipelago belong to the equatorial (tropical) zone whereas Mauritius, Rodrigues and Réunion (which form the Mascarenes) are subtropical. Réunion and parts of the Comoros archipelago (Grande Comore and Anjouan), with maximum altitudes ranging from 1 500 m asl (above sea level) to more than 3 000 m asl, offer the widest variety of habitats. The isolation of the islands from the nearest continental land mass also varies dramatically, from 280 km for Grande Comore to more than 1 400 km from Madagascar for Rodrigues. Age, size, altitude and distance of the islands from the nearest continental land mass especially affect the level of endemism. The highest numbers of plant species endemic to any one archipelago are found on bigger islands such as Réunion (c. 165 Réunion and a further 135 Mascarene endemics; island area: 2 512 km²), the island of Mauritius (c. 287 Mauritian and further 122 Mascarene endemics; 1 865 km²), and the Comoros archipelago (136 Comorian endemics; 2 033 km²), whereas the granitic Seychelles (c. 230 km²) has around 80 endemic plant species and Rodrigues (109 km²) has around 68 endemic plant species (44 Rodriguan and a further 24 Mascarene endemics) only. However, in terms of endemic plant species per square kilometre, the older or more isolated islands of Rodrigues (0.62 endemic plant species per square kilometre) and of the granitic Seychelles (0.35/km²) are the richest, compared with 0.12/km² in Réunion, 0.07/km² in the Comoros archipelago and 0.22/km² in Mauritius.

In terms of socio-economic development the major discrepancy is between the Union of the Comoros and the other small island countries and territories. In the Comoros, deforestation is still progressing quickly whereas in the other small islands, which have a higher GNP (Gross National Product) per inhabitant, service-oriented economies are now paying much attention to the protection of their environment.

Despite these differences, small islands within the region share many common characteristics:

- They are a priority area for international conservation.
- The Western Indian Ocean has been identified as a Biodiversity Hotspot (Conservation International, Myers *et al.* 2000), as a Global 200 Ecoregion (WWF–US [Worldwide Fund for Nature – United States], Olson and Dinerstein 1998) and as a Center of Plant Diversity (WWF, IUCN). Because of the unique natural history and habitats of the Western Indian Ocean islands they are also important in representing unique habitats and natural processes, a point of view underestimated by the hotspot concept (the 'representation approach', see Olson and Dinerstein 1998). Endemism is high.
- Small oceanic islands are particularly prone to invasion by exotic species (e.g. Stone *et al.* 1992; Cronk and Fuller 1995; Lonsdale 1999), which are the main threat to native biodiversity in all the surveyed small islands, except the Comoros archipelago where forests are still disappearing rapidly because of deforestation.

- Resources of small oceanic islands are limited in terms of both funding and capacity, which makes it a challenge for them to organize the fight against invasive species. Conscious of their weaknesses, regional small islands have gathered to constitute a political voice under the banner of the Indian Ocean Commission. Formal regional cooperation is also developing. Such initiatives allow funds from various donors to be accessed, including the European Commission and French cooperation, and increase the subregion's credibility in the eyes of international agencies, which are now more and more in favour of regional approaches to environmental issues.

4. INVASION HISTORY

Four main phases of human interference in the small islands of the Western Indian Ocean can be distinguished:

- Phase 1: early settlements (non-permanent or very small settlements; before c. 1760);
- Phase 2: early colonial phase (first permanent settlements, start of agriculture, fast growth of colonies; c. 1760–1830);
- Phase 3: colonial exploitation (main colonial phase, explosive population growth; c. 1830–1950);
- Phase 4: post-colonial era (independence, reorientation from primary to tertiary sector; second half of the twentieth century).

During phase 1 the impact on natural habitats was minor. The main introductions were exotic animals (rats, pigs, goats, cattle, deer). A few main invasive woody plant species, mostly fruit trees, were introduced during this period in some small islands (e.g. Mauritius: *Psidium cattleianum*, *Flacourtia indica*, *Syzygium jambos*). For many of the early introductions the status (exotic, native) is not clarified (e.g. *Casuarina equisetifolia*, *Cocos nucifera*).

Phase 2 saw the introduction of the majority of the main invasive woody plant species (e.g. *Acacia nilotica*, *Ardisia crenata*, *Cinnamomum verum*, *Lantana camara*, *Leucaena leucocephala*, *Litsea monopetala*, *Livistona chinensis*, *Rubus alceifolius*, *Solanum mauritianum*, *Ulex europaeus*), except in Seychelles. The first botanical gardens were established during this period (Pamplemousses in Mauritius in 1736; Jardin du Roi in Réunion in 1761; Jardin du Roi in Seychelles in 1772). Large-scale agriculture started (cotton [*Gossypium* spp.], sugar cane [*Saccharum officinarum*], coffee [*Coffea* spp.], cloves [*Syzygium aromaticum*]). During this time, also, most of the lowland forests disappeared. In the Comoros archipelago, however, these developments were delayed by approximately half a century.

In phase 3 population growth and large-scale agriculture exploded. Most of the forest cover disappeared, except in Réunion and the Comoros archipelago. The emancipation of slaves in the middle of the nineteenth century put further pressure on remote forests. Around 1900 the colonial administrations started reforestation programmes with exotic species (especially legumes and *Pinus* and *Eucalyptus* spp.). This large-scale planting contributed surprisingly few of the main invasive woody plant species. This is partly because *Pinus* and *Eucalyptus* species are not yet very problematic in the region, although the Leguminosae has contributed more invasive species to the region than any other plant family. Seychelles is an exception to this pattern of introduction, as most of its main invasive woody plant species were introduced in this phase (*Ardisia elliptica*, *Chrysobalanus icaco*, *Hevea brasiliensis*, *Leucaena leucocephala*, *Paraserianthes falcataria*, *Pentadesma butyracea*, *Psidium cattleianum*, *Sandoricum koetjape*, *Syzygium jambos*, *Tabebuia pallida*).

The planting of exotic species continued on a large scale well into the 1970s in the Mascarenes and Seychelles and is still continuing in the Comoros archipelago. At the present time, forestry activities are in decline or have stopped almost completely, except in the Comoros archipelago where deforestation is still the main threat to the native flora and fauna. Between the 1970s and the 1980s tourism and, in parallel, an awareness of the invasive species problem arose. In this fourth phase new invasive woody plant species were largely introduced as ornamentals (e.g. *Ardisia crenata* and *Dillenia suffruticosa* in Seychelles), although *Clidemia hirta* was introduced accidentally.

The introduction of exotic woody plant species in the region is in asynchrony to the worldwide pattern. On a global scale, introductions of exotic forestry and agroforestry species started mainly in the twentieth century and rapidly expanded during the 1980s (Richardson 1998).

5. INVASIVENESS

5.1. Conclusions/Synthesis

Four categories of invasiveness based on expert judgments and literature have been used in this study. Assessments were undertaken separately for each country and territory, then a summary prepared for the region. The categories are as follows:

1. The *most problematic species* are widely accepted by participants in this study to be very problematic and to be a priority for management.
2. The *main invasive species* include the most problematic species together with less problematic species that are nonetheless widely accepted as invasive.
3. *Non-consensus species* are rated as invasive by a subset of the available literature and experts.
4. *Potentially new invasive species* are naturalized. In addition, they are known to be invasive elsewhere in the world, and/or are showing strong tendencies to invade secondary or primary vegetation in the affected island.

Overall, for each country or territory studied we identified fewer than ten most problematic woody plant species, 10–20 main invasive species, another 10–20 non-consensus species, and 20–100 potentially invasive species (Table 1). In total, there are 46 main invasive woody plant species in the region, of which 20 are classified as most problematic species (see Tables 2 and 3).

All species that are present in either both equatorial island groups (Seychelles, Comoros archipelago) or in both Mascarenes island groups (Réunion, Mauritius) are among the most problematic species in at least one island, except *Leucaena leucocephala*. *Leucaena leucocephala* is widespread in all islands, but occurs mainly in lowland secondary vegetation where the negative impact on natural vegetation is minor. All of the most problematic species of the Western Indian Ocean region were rated as moderately or highly invasive by Binggeli *et al.* (1998), except *Alstonia macrophylla* and *Ardisia crenata*.

The similarity of the invasive woody plant species of the Mascarenes is higher than for the equatorial island groups (Seychelles, Comoros archipelago) (see Tables 2 and 3). One might expect that this is because of the more frequent travel and transport between the Mascarene islands. However, most of the main invasive species of the Comoros archipelago that are not invasive in Seychelles have, all the same, been widely planted in there (i.e. *Acacia mangium*, *Albizia lebeck*, *Gliricidia sepium*, *Psidium guajava*, *Spathodea campanulata*, *Syzygium aromaticum*).

In Table 4, the main invasive woody plant species are summarized according to why they were introduced. Under the category agroforestry we included species that were introduced for products other than wood, i.e. fruits, spices and medicinal products. The category ornamentals includes species planted in gardens and parks and introductions to a botanical garden. ‘Others’ includes species introduced for purposes such as shade, windbreaks and, especially, erosion control.

Looking at the most problematic species in the region, the ornamentals are by far the most prominent group, and the proportion of most problematic to main invasive species is also highest for the ornamentals, except the single case of the accidental introduction of *Clidemia hirta*. Comparing countries, the proportions of main invasive species introduced as timber trees in Seychelles and ornamentals in Réunion are especially high. In contrast, in the Comoros archipelago the proportion of main invasive species introduced as ornamentals is especially low and agroforestry species are more prominent.

TABLE 1: INVASIVENESS OF WOODY PLANT SPECIES IN THE WESTERN INDIAN OCEAN
Number of species per category

Country/territory	Category ^a			
	I	II	III	IV
Comoros ^b	8	16	13	c. 20
Réunion	10	18	14	c. 100
Mauritius	9	17	24	c. 10
Seychelles	6	20	10	c. 20

^a I: Most problematic species; II: Main invasive species; III: Non-consensus species; IV: Potentially invasive species.

^b The Union of the Comoros and the French Territorial Collectivity of Mayotte.

TABLE 2: THE INVASIVE WOODY PLANT SPECIES THAT ARE VERY PROBLEMATIC IN AT LEAST ONE SMALL ISLAND COUNTRY OR TERRITORY OF THE WESTERN INDIAN OCEAN REGION

Species	Country/territory ^a				Tropics ^b
	Comoros ^c	Réunion	Mauritius	Seychelles	
<i>Acacia auriculiformis</i>	**	(*)			3
<i>Acacia mangium</i>	**			(*)	
<i>Alstonia macrophylla</i>	r	r	r	**	
<i>Ardisia crenata</i>		*	**	*	1
<i>Casuarina equisetifolia</i>	(*)	**	(*)	**	3
<i>Cinnamomum verum</i>	*	(*)	(*)	**	2
<i>Clidemia hirta</i>	**	**	*	*	3
<i>Hiptage benghalensis</i>		**	**		2
<i>Lantana camara</i>	**	**	**	*	3
<i>Ligustrum robustum</i> subsp. <i>walkeri</i>		**	**		3
<i>Litsea glutinosa</i>	**	*	(*)	(*)	3
<i>Paraserianthes falcataria</i>	r			**	2
<i>Psidium cattleianum</i>	**	**	**	**	3
<i>Ravenala</i> <i>madagascariensis</i>		(*)	**	(*)	3
<i>Rubus alceifolius</i>	(*)	**	**		3
<i>Schinus terebinthifolius</i>		*	**		3
<i>Solanum mauritianum</i>	(*)	**	(*)		3
<i>Spathodea campanulata</i>	**	(*)	(*)	(*)	2
<i>Syzygium jambos</i>	**	**	**	**	2
<i>Ulex europaeus</i>	r	**	(*)		3

^a r: High risk of invasion if introduced; (*): Potentially invasive or non-consensus; *: Main invasive; **: Most problematic invasive.

^b 1: Potentially invasive; 2: Moderately invasive; 3: Highly invasive (according to Binggeli *et al.* 1988).

^c The Union of the Comoros and the French Territorial Collectivity of Mayotte.

TABLE 3: MAIN INVASIVE SPECIES THAT ARE NOT AMONG THE MOST PROBLEMATIC SPECIES IN ANY SMALL ISLAND COUNTRY OR TERRITORY IN THE WESTERN INDIAN OCEAN
i.e. Are not included in Table 2

Country/territory	Other main invasive woody plant species
Comoros ^a	<i>Albizia lebbbeck</i> , <i>Gliricidia sepium</i> , <i>Jatropha curcas</i> , <i>Leucaena leucocephala</i> , <i>Psidium guajava</i> , <i>Senna</i> sp., <i>Syzygium aromaticum</i>
Réunion	<i>Fuchsia</i> × <i>exoniensis</i> , <i>Fuchsia magellanica</i> , <i>Leucaena leucocephala</i> , <i>Prosopis juliflora</i> , <i>Tibouchina viminea</i>
Mauritius	<i>Acacia nilotica</i> , <i>Flacourtia indica</i> , <i>Homalanthus populifolius</i> , <i>Leucaena leucocephala</i> , <i>Litsea monopetala</i> , <i>Livistona chinensis</i> , <i>Tabebuia pallida</i>
Seychelles	<i>Adenantha pavonina</i> , <i>Carica papaya</i> , <i>Chrysobalanus icaco</i> , <i>Cocos nucifera</i> , <i>Dillenia suffruticosa</i> , <i>Hevea brasiliensis</i> , <i>Leucaena leucocephala</i> , <i>Memecylon caeruleum</i> , <i>Pentadesma butyracea</i> , <i>Sandoricum koetjape</i> , <i>Tabebuia pallida</i>

^a The Union of the Comoros and the French Territorial Collectivity of Mayotte.

TABLE 4: PRINCIPAL PURPOSE FOR INTRODUCING THE MAIN INVASIVE WOODY PLANT SPECIES IN THE WESTERN INDIAN OCEAN

Number of species (percent)

		Wood	Agroforestry	Ornamental	Accidental	Others
Country/ territory	Comoros ^a	3 (20%)	7 (46.7%)	2 (13.3%)	1	2 (13.3%)
	Réunion	2 (11.1%)	5 (27.8%)	10 (55.6%)	1	0
	Mauritius	1 (5.9%)	6 (35.3%)	8 (47.1%)	1	1 (5.9%)
	Seychelles	6 (30%)	8 (40%)	4 (20%)	1	1 (5%)
Region	Main invasive	10 (21.7%)	15 (32.6%)	16 (34.78%)	1 (2.1%)	4 (8.7%)
	Most problematic	5 (25%)	5 (25%)	9 (45%)	1	

^aThe Union of the Comoros and the French Territorial Collectivity of Mayotte.

TABLE 5: THE NUMBER (AND PERCENTAGE) OF MAIN INVASIVE WOODY PLANT SPECIES OF THE WESTERN INDIAN OCEAN GROUPED ACCORDING TO PLANT TYPE^a

Country/territory	Large trees (> 15 m)	Small trees (< 15 m)	Shrubs (< 5 m)
Comoros ^b	7 (43.8%)	4 (25.0%)	5 (31.3%)
Réunion	3 (16.7%)	7 (38.9%)	8 (44.4%)
Mauritius	5 (31.3%)	6 (37.5%)	5 (31.3%)
Seychelles	10 (50.0%)	7 (35.0%)	3 (15.0%)
Binggeli (very invasive) ^c	34 (20.9%)	32 (19.6%)	97 (59.5%)
Binggeli (all) ^c	166 (27.2%)	181 (29.6%)	264 (43.2%)

^a For comparison, percentages from a survey of invasive woody plant species in the tropics are given (Binggeli 1996).

^b The Union of the Comoros and the French Territorial Collectivity of Mayotte.

^c Binggeli (very invasive) takes into consideration only the very invasive species in the survey; Binggeli (all) refers to all species included in the survey (very, moderately and potentially invasive).

TABLE 6: THE TAXONOMIC DISTRIBUTION OF THE MAIN INVASIVE SPECIES OF THE WESTERN INDIAN OCEAN, COMPARED WITH DATA FROM THE ENTIRE TROPICS

Number of species (percent)

Family	Most invasive	Main invasive	Tropics ^a
Bignoniaceae	1	2 (4.2%)	
Euphorbiaceae		3 (6.3%)	
Lauraceae	2	3 (6.3%)	
Leguminosae	2	10 (20.8%)	97 (14.9%)
Melastomataceae	1	3 (6.3%)	
Myrtaceae	2	4 (8.3%)	20 (3%)
Onagraceae		2 (4.2%)	
Palmae		2 (4.2%)	
Others	12	17	
TOTAL (all families)	20	46	?

^aData from Binggeli (1996).

A recent global review of invasive forestry trees (Haysom and Murphy 2003) stated that 64 percent are forestry species, 44.7 percent are agroforestry species, and 62.4 percent are amenity species (equivalent to our ornamentals and others categories). This is only partially comparable with the data in Table 4 because we looked at only the main reason for the introduction while Haysom and Murphy analysed all uses separately. Even so, less than 50 percent of the invasive woody plant species in the region are used as forestry species to any extent. Forestry species make up a smaller proportion of the invasive woody plant species on a regional than global scale.

Seven (41.2 percent) of the most problematic species of the region are large trees (> 15 m high), five (29.4 percent) are small trees (< 15 m) and five (29.4 percent) are shrubs (not included in this analysis is the creeper *Hiptage benghalensis*). Many tree species are very fast growing (e.g. *Alstonia macrophylla*, *Paraserianthes falcataria*, *Ravenala madagascariensis*).

A similar pattern can be seen for individual islands (see Table 5). However, the percentage of large trees is especially high in Seychelles and the Comoros archipelago, while the percentage of invasive shrubs is especially high in Réunion, but markedly lower than for other islands in Seychelles. Binggeli (1996) found a distinctly higher percentage of invasive and highly invasive shrubs compared with other plant forms in his review of invasive woody plant species throughout the tropics (see Table 5).

According to Binggeli (1996) the plant families with the most invasive woody plant species are the Rosaceae (15 percent of the invasive species identified), the Leguminosae (Caesalpiniaceae, Mimosaceae, Papilionaceae) (14.9 percent), the Pinaceae (4.1 percent) and the Myrtaceae (3 percent). In another recent survey (Haysom and Murphy 2003) most invasive forestry species were drawn from the families Leguminosae, Pinaceae, Myrtaceae, Rosaceae and Salicaceae (in decreasing order).

The Rosaceae contains only one invasive species in the Western Indian Ocean region, and there are no invasive Pinaceae. On the other hand, the number of invasive Leguminosae is very high, accounting for one-fifth of the main invasive species in the region, and the percentage of invasive Myrtaceae is more than double that found in the tropics as a whole (Table 6).

In all countries and territories of the region, some 50 percent of the main invasive species are bird dispersed, and about another 25 percent are wind dispersed (mainly nitrogen-fixing Leguminosae). Almost all of the main invasive species were introduced 100–200 years ago.

Most species mainly invade disturbed, open, secondary habitats. The exceptions to this rule are especially problematic species:

- A small number of species are extremely ecologically plastic, invading almost all habitats from the lowlands to the high-altitude mountain forests: *Cinnamomum verum*, *Clidemia hirta* and *Psidium cattleianum* (especially at higher altitudes) and *Rubus alceifolius* (although it only invades gaps).
- Some species are shade tolerant, and capable of invading natural, undisturbed, closed canopy forests: *Ardisia crenata*, *Cinnamomum verum*, *Clidemia hirta*, *Fuchsia* spp., *Ligustrum robustum* subsp. *walkeri*, *Litsea glutinosa*, *Psidium cattleianum* and *Syzygium jambos*.

- A few species invade habitats with harsh conditions that are generally resistant to invasion: *Alstonia macrophylla* and *Cinnamomum verum* (glacis [inselbergs] in Seychelles), *Ulex europaeus* (high-altitude ericaceous vegetation in Réunion), *Boehmeria penduliflora* and *Casuarina equisetifolia* (early successional stages on volcanic lava flows in Réunion), and *Acacia mangium* and *Acacia auriculiformis* (padzas [badlands] in the Comoros archipelago).

5.2. Recommendations

- The number of very problematic woody plant species in the region is small (20). These species should be a priority for control measures in the field. Most of them are well known from other parts of the tropics, and occur in several countries and territories within the region. Information on the ecology and management of these species is mostly available (e.g. Weber 2003). Knowledge should be shared within the region, and management efforts coordinated.
- A number of the very problematic species are potentially very invasive in islands where they are not invasive at present or have not yet been introduced. This applies especially to *Paraserianthes falcataria* in the Comoros archipelago, *Ulex europaeus* in the higher altitudes of the Comoros archipelago, *Alstonia macrophylla* in the Mascarenes and the Comoros archipelago, and *Spathodea campanulata* in Seychelles. For these species special attention should be given to prevention measures.
- Some of the species that are classified as non-consensus species in one island are invasive or at least also non-consensus species in other islands of the region. Consequently, careful monitoring is recommended for various species in specific islands. Comoros archipelago: *Adenanthera pavonina*, *Anacardium occidentale*, *Annona squamosa*, *Casuarina equisetifolia*, *Rubus alceifolius* and *Solanum* spp.; Mauritius: *Albizia lebeck*, *Ardisia elliptica*, *Camellia sinensis*, *Cinnamomum verum*, *Solanum mauritianum* and *Tibouchina viminea*; Réunion: *Flacourtia indica* and *Ravenala madagascariensis*; Seychelles: *Anacardium occidentale*, *Annona squamosa*, *Camellia sinensis*, *Cananga odorata* and *Spathodea campanulata*.
- All of the current main invasive species, except *Clidemia hirta*, were deliberate introductions, and the number of woody ornamentals that become invasive will probably increase in the future. For instance, in Seychelles all recently introduced, newly spreading species except *Clidemia hirta* are ornamentals. Ornamentals are often shrubs, which seem in general to be more invasive than trees in the tropics (Binggeli 1996). The preponderance of most problematic species among the main invasive ornamentals suggests that ornamentals are especially problematic in the region. Better control of deliberate introductions, especially ornamentals, is needed.

6. INVASIBILITY OF HABITATS

Most of the invasive species are pioneer species that prefer high light levels. Hence, the invasibility of habitats is enhanced when anthropogenic activities lead to the opening of gaps, and is therefore directly correlated with deforestation and habitat destruction.

On all islands surveyed, the lowland forests have almost totally disappeared and are replaced by secondary forests composed of exotic species, except for patches of vegetation that have been saved either because of their topography or because they offered very poor conditions for agriculture (e.g. glacis [inselbergs] in Seychelles, coastal dry areas in Mayotte, some small patches of lowland forest in the Mascarenes).

Intermediate-altitude forests are typically highly invaded as they have also suffered from heavy disturbance in the past.

Some habitats pose resistance to invasion, including glacis in Seychelles, early successional stages of volcanic lava flows in Réunion and the Comoros archipelago, and padzas in Mayotte. Mountain forests on all islands are also less prone to invasion, as long as they are not disturbed.

7. ENVIRONMENTAL AND ECONOMIC IMPACTS

The main effect of invasive species noted in the islands surveyed is to outcompete native species. This often takes place through the formation of thickets and monospecific stands. Allelopathy was mentioned for several species as a possible competition mechanism (*Cinnamomum verum*, *Lantana camara*, *Syzygium jambos*, *Ligustrum robustum* subsp. *walkeri*) but this has not been proved so far for any of them.

In addition, some examples of transformer species were found. Ecosystem-level effects mentioned were:

- The enrichment of the soil nutrients by nitrogen-fixing invasive species (especially Leguminosae such as *Paraserianthes falcataria* and several *Acacia* spp., and *Casuarina equisetifolia*);
- The impact on the water budget of some invasive species (e.g. fast growing species such as *Acacia nilotica* and the non-invasive *Eucalyptus* sp. on Rodrigues);
- The lower resistance of exotic species to cyclones in the Mascarenes, which leads to increased erosion on steep slopes and especially to a higher frequency of gaps and secondary invasions.

Biological interactions between different trophic levels were rarely studied. In general, native (animal) species clearly prefer native vegetation but there are examples where native species adapt well to exotic vegetation (see, for example, Part 5: Seychelles, Box 3: The impact of invasive plants on native insects in Seychelles and Box 4: Synopsis of the interrelationship between native birds and alien vegetation in Seychelles). In the case of the endemic land birds, there were examples in all islands studied of rare endemic species relying, at least partly, on exotic, secondary vegetation. For example: white-eye (*Zosterops modestus* in Seychelles, *Zosterops borbonicus* in Réunion and Mauritius), fody (*Foudia rubra* in Mauritius, *Foudia flavicans* in Rodrigues), warbler (*Acrocephalus rodericanus* in Rodrigues) and drongo (*Dicrurus fuscipennis* in the Comoros archipelago). However, most endemic bird species seem to prefer or need native vegetation. In Mauritius and Réunion, there is currently active research studying differences in biodiversity between native and exotic vegetation (see Part 3: Mauritius and Part 4: Réunion). This is surely a promising route that should be further developed.

An example of an interaction between different trophic levels is the mutualistic relationship between exotic fruits (notably *Psidium cattleianum*) and exotic animals that was formulated in Réunion and Mauritius. In Mauritius, it was suggested that fruit production of *P. cattleianum* in the austral winter when native fruit availability is generally low maintains high densities of pigs and monkeys. These exotic animals will then be at high densities at the end of the fruiting season of *P. cattleianum* when the main breeding season for native birds and the fruiting season for native trees begins. Monkeys cause significant damage to both native birds and trees. Pigs in turn disturb forest trees and ferns and may cause considerable damage to ground-dwelling invertebrates.

No case of hybridization of an invasive species has ever been recorded with certainty in the region, although *Rubus alceifolius* has probably hybridized in Madagascar with a native *Rubus* species. A risk of hybridization was also noted for some other exotic species.

No human health impacts from invasive woody plant species have been observed in the region.

The main issue regarding the impacts of invasive woody plant species is the existing knowledge gap, which was acknowledged in all islands surveyed. Few data exist on the management of invasive plant species themselves, and even fewer data are available regarding impacts on invertebrates, epiphytes, fungi, etc. A huge amount of research and monitoring still needs to be undertaken.

In terms of civil society's perception of the problems caused by invasive plant species, the surveyed islands fall into two groups.

- In the Union of the Comoros, the main concern is economic, as agriculture employs more than 70 percent of the national work force and – given the low trading power of the country – has to feed the population. In this country, therefore, the main concern regarding invasive plant species is the difficulty and cost of their eradication on agricultural land.
- In all other islands, where the economies are more developed, the main concern regarding invasive plant species is their role in the loss of biodiversity.

8. CONTROL MEASURES AND HABITAT RESTORATION

8.1. Control measures

Mechanical control measures have been the main interventions so far in all small island countries and territories for two obvious reasons: they do not involve products and scientific know-how that are very expensive and often not available locally, and they can be applied with minimal unwanted impacts on the environment.

Chemical control is often applied in combination with mechanical control, to which it brings greater efficiency. However, its use has to be carefully planned to avoid negative impacts on the environment. For instance, the use of chemicals in Seychelles on experimental plots rich in biodiversity has led to the death of endemic plants close to the treated exotic plants (see the description of the Congo Rouge experiment in Part 5: Seychelles, Section 7.1.6. Control of invasions).

Experiences of mechanical and chemical control are scattered among different agencies as well as within agencies. In Réunion, the Forestry Service (ONF–Réunion) has just completed a synthesis study that summarizes their past experiences of mechanical and chemical control. Two general conclusions can be drawn from the study (see Part 4: Réunion, Box 1: Invasive plant species control methods – experiences of the Office national des forêts, Réunion).

1. Some integrated measures (chemical and mechanical control combined with habitat management) were effective and had relatively little negative environmental impact while other interventions were not effective or had considerable negative impact. Hence, it is valuable to share experiences and improve methods.
2. It often proved difficult to decide why a specific method did not work. Local factors play a crucial role in the success of control (period of application, experience of the labour force, choice of chemical product, application method ...). A standard protocol should be developed and tested for reporting on invasive species control trials.

Biological control has so far been researched or implemented only in Réunion and Mauritius. It is very expensive and needs careful preparation. Nevertheless, it is one promising option for scaling up invasive species control from local attempts to landscape-wide restoration. However, it has to be borne in mind that the removal of an unwanted species alone does not solve the problem: it is likely that another invasive species will replace it.

Currently, two biological control research projects are underway in Réunion, one on *Rubus alceifolius* and the other on *Ligustrum robustum* subsp. *walkeri* (Part 4: Réunion, Section 7.1. Case Study: *Rubus alceifolius* and Section 7.2. Case Study: *Ligustrum robustum* subsp. *walkeri*). So far, no biocontrol agents have been identified that have passed through all safety tests.

The biggest potential for biological control in the region would be against *Lantana camara* and *Psidium cattleianum*, the populations of which have become unmanageable and for which potential biological control agents are known.

8.2. Habitat restoration

Apart from the Union of the Comoros, all islands have instigated habitat restoration initiatives.

Generally, successful restoration activities prove to have:

- The long-term commitment of both the donor agency and the implementing agency (when they are not the same organization) to the follow-up management of the eradication/restoration process. This commitment has to materialize in terms of both financial and human resources. In Seychelles and the Comoros archipelago, donor agencies have been especially criticized for stopping projects before their objectives are achieved.
- The support and commitment of the local population.

The cost of habitat restoration depends on the local conditions and situation. For instance in Mauritius, proper restoration will require fencing to avoid incursions by pigs and deer, which is not necessary in other islands that are free of these animals.

In all cases, habitat restoration is very expensive. As an example, initial restoration activities in Seychelles are estimated to amount to US\$16 500/ha in lowland areas and up to \$50 000/ha in upland areas. The fencing of Mauritian Conservation Management Areas (CMAs) costs some US\$20 000/ha alone, whereas the annual weeding cost is estimated to amount to \$2 000/ha. In Réunion, mean total costs per hectare for restoration were estimated at €46 000 for lowland humid forest but €24 000 for lowland dry forest (see Part 3: Mauritius, Part 4: Réunion and Part 5: Seychelles).

As it is expensive, habitat restoration has so far been undertaken on only a very small scale (20–100 ha per small island). The most efficient use of the available resources needs to be made. The following strategies show promise:

8.2.1. Habitat restoration through spatial planning and prioritization

The following criteria should be assessed:

- The visibility of the restoration initiative, so that local inhabitants and tourists can benefit from it and the site can be used for educational purposes;
- The feasibility of the restoration, in terms of accessibility of the sites targeted, their infestation rate, and the immediate and mid- to long-term cost of the restoration;
- The estimated rate of success;
- The biodiversity value of the sites targeted, which should contain a high percentage of surviving (rare) native species;
- The need to diminish propagule pressure by targeting open areas where fruit production is prolific (e.g. glacis [inselbergs], forest edges) and by restoring the closed canopy in forested areas to diminish light levels and prevent regrowth of exotics.

8.2.2. Restoration efforts adapted to local conditions

Based on experiences from pilot projects, restoration efforts should be fine-tuned and adapted to the local conditions. This includes the adequate combination of mechanical, chemical and biological control and habitat management. Efficiency can be greatly increased and the negative impact of restoration measures reduced (see Part 4: Mauritius, Section 4.2. Restoration activities and Part 5: Seychelles, Box 5: Habitat restoration in the Morne Seychellois National Park).

8.2.3. Evaluation of positive and negative impacts of restoration efforts

It is important that research accompanies restoration projects as they progress, so that their impacts can be better understood, and targets are defined.

Restoration activities can lead to negative impacts on the native fauna such as, for instance, benefiting exotic species (e.g. exotic snails in Mauritius), or threatening rare species that have managed to adapt to exotic vegetation (e.g. the white-eye bird in Seychelles).

Knowledge of the positive impacts of restoration initiatives on the abundance of invertebrates, epiphytes, fungi and other neglected taxonomic groups is also clearly needed.

8.2.4. Mainstreaming habitat restoration

As successive restoration projects take place, in the long run self-financing and cofinancing should be encouraged. A few examples given in this report, such as the proposed parallel management of invasive species and water scarcity in Rodrigues, the sustainable commercial use of cinnamon and timber trees in Seychelles, and the direct financing of habitat restoration through ecotourism, are some directions to be pursued.

9. AWARENESS AND CONFLICTS OF INTEREST

9.1. Awareness

Awareness is high among experts, and within governmental institutions and NGOs, except for the Union of the Comoros where, in the main, only the experts are aware of the issue.

In Seychelles, Réunion, Mauritius and Mayotte, awareness has risen during the past ten to 20 years.

Awareness is low among politicians and the general public, except in Seychelles where the widespread development of wildlife clubs in schools and the omnipresence of environmental programmes in the media have made the sensitivity of the public to environmental issues more acute.

However, until now awareness-raising regarding invasive plant species has taken place in all countries and territories through scattered events and not through any properly articulated long-term campaign.

A national invasive species committee has recently been set up in Mauritius and Réunion, and is under discussion in Seychelles.

9.2. Conflicts of interest

Conflicts of interest are generated when invasive species are widely used on a day-to-day basis. In the region, the following categories of use seem to lead to open or potential conflicts of interest.

9.2.1. Erosion control

All islands are affected. The species used are either herbaceous or woody plant species, and have the characteristics of fast growth, an extensive root system, and tolerance of poor soil conditions. For example, *Acacia mangium* is now regenerating rapidly in the Comoros archipelago. Seychelles, which is still planting the species for erosion control, should rethink its strategy. Herbaceous species such as *Vetiveria zizanioides* have been proposed as alternatives for erosion control. However, *V. zizanioides* has also proved to be invasive in the Union of the Comoros.

To avoid conflicts of interest regarding erosion control issues that are crucial to all islands, some are undertaking experiments with endemic species (e.g. palms in Mayotte and Seychelles).

9.2.2. Wood

Apart from the Union of the Comoros, all other islands have experienced a decline of the forestry sector, and timber tree species do not seem to be generating conflicts of interest. In the Union of the Comoros, the lack of wood is so severe that even species usually considered as non-timber species (e.g. *Psidium cattleianum*) are used for building. The conflict of interest there is self-evident.

9.2.3. Ornamentals

Exotic ornamentals are still frequently introduced in all countries and territories and there is little awareness among the populations and the stakeholders who are directly involved (horticulturalists, importers). As most of the main invasives on islands in the region are ornamentals, one of the major challenges for the future will certainly be to control their introduction and educate people on their effects.

9.2.4. Fruit trees

Psidium cattleianum is valued as a fruit tree in all islands except Seychelles. In general, in the Union of the Comoros the fruit of all invasive fruit tree species (e.g. *Psidium guajava*, *Citrus* spp.) are consumed regularly.

9.2.5. Spices

In the Comoros archipelago, controlling *Cinnamomum verum* and *Syzygium aromaticum* could potentially lead to conflict.

9.2.6. Multipurpose exotic species

In the Comoros archipelago, a few invasive woody plant species are used in agriculture as forage or as vanilla (*Vanilla planifolia*) ‘tutors’ (poles on which vanilla plants can climb and develop), as fuelwood, for construction, and for medicinal purposes. These ‘talented’ plants are those for which conflicts of interest could be the most dramatic. Principal species in this category are *Psidium cattleianum*, *Litsea glutinosa*, *Gliricidia sepium* and *Albizia lebbek*.

10. LEGISLATION

All small island countries and territories that took part in the survey have, until now, developed plant protection legislation that mainly targets the control of weeds and pathogens, and related quarantine legislation. Laws and regulations are applied efficiently in Mauritius and Réunion.

None of the small islands has so far put together legislation for invasive species. However, in Réunion an adaptation of the plant protection legislation for the purpose of invasive species management is under discussion. A black list (of species for which importation is prohibited), a white list (of species for which importation is not regulated) and the precautionary principle should be included in national legislation.

The development of a screening system (risk assessment of potentially new invasive species), adapted from systems in the Pacific region, should be encouraged on a regional scale.

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APPENDICES

Appendix 1: list of abbreviations and acronyms

3P	Pôle de Protection des Plantes, Réunion
asl	above sea level
BRG	Black River Gorges National Park, Mauritius
CIRAD	Centre International de Recherche pour le Développement
CMA	Conservation Management Area
CNDRS	Centre National de la Recherche Scientifique, Comoros
DAF	Direction de l'Agriculture et de la Forêt
DIREN	Direction Régionale de l'Environnement, Réunion
ETH	Swiss Federal Institute of Technology
FAO	Food and Agriculture Organization of the United Nations
FDGDON	Fédération des Groupements de Défense contre les Organismes Nuisibles, Réunion
GDP	Gross domestic product
GEF	Global Environment Facility
GNP	Gross National Product
ICS	Island Conservation Society
INVABIO	National biological invasions research programme, Réunion
IUCN	World Conservation Union
MFS	Mauritius Forestry Service
MOE	Ministry of Environment & Natural Resources (previously Ministry of Environment)
MRSAS	the Mauritius Royal Society of Arts and Sciences
MSIRI	Mauritius Sugar Industry Research Institute
MWF	Mauritian Wildlife Foundation
NGO	Non-Governmental Organization
NPCS	National Parks and Conservation Service, Mauritius
NPTS	Nature Protection Trust of Seychelles
ONF	Office National des Forêts
PCA	Plant Conservation Action Group
REEP	Rodrigues Environmental Education Programme, Mauritius
RFS	Rodrigues Forestry Service, Mauritius
SEF	Service des Eaux et Forêts, Comoros
SIF	Seychelles Island Foundation
SPV	Service de la Protection des Végétaux
SREPEN	Société Réunionnaise pour l'Etude et la Protection de l'Environnement
UNEP	the United Nations Environment Fund
UNESCO	United Nations Educational, Scientific and Cultural Organization

Appendix 2: questionnaire on invasive woody plant species, Seychelles

The following questionnaire was filled in by:

Name:
Organization:
Please give a brief description of the expertise you or your organization have concerning invasive plant species in the Seychelles:

A) Invasion in general

“What does the problem of invasive plant species mean to you?”

1. Please give your definition of an invasive species:

2. Relevance of the invasive species problem:
 - What is the relevance of the invasive species problem for the Seychelles in general, its environment, its economy, its society?

 - More specifically, what is the relevance of the invasive species problem for nature conservation in the Seychelles?

B) Invasive species

3. Main invasive woody plant species in the Seychelles:

Please specify the most problematic invasive woody plant species in the Seychelles. Please indicate to which islands you are referring and why you think these species are problematic.

Species (Latin and vernacular name)	Islands	Rating (Very problematic, problematic, rather unproblematic)	Reasons for your rating

4. Which non-woody species or groups of species would you consider as invasive?

Species (Latin and vernacular name)	Islands	Reasons for concern

5. Exotic species that are not invasive:

Please specify exotic woody plant species in the Seychelles that are not invasive (i.e. not spreading, no negative impacts) although you would expect it, e.g. because they are frequently planted in the Seychelles or because they are invasive in other places. Please comment, why according to you, they are not invasive.

Species (Latin and vernacular name)	Comment

6. Expansion of new invasive plant species:

Please list invasive woody plant species that are already established on some Seychelles islands or in neighboring countries (e.g. Mauritius, Réunion) and where there is a risk that they will further spread? (Example: *Clidemia hirta* is already established on Silhouette and Mahé but not yet on Praslin)

Species (Latin and vernacular name)	Already established on	May spread to

Species related questions:

Here you are presented with a list of woody plant species. We are interested in the following data related to them:

- Date of first introduction to the Seychelles
- Areas where the species is currently present and extent of invasion within these
- Biological characteristics:
 - o Minimum juvenile period (age, height of plant at first production)
 - o Fruiting season (once or several times per year)
 - o Length of fruiting period
 - o Dispersal mechanism (birds, bats, wind, gravity, others)
 - o Seed germination requirements
 - o Herbivores: Have you observed herbivores on the specific species in the Seychelles?

Trees:

Species	Date introduced	Areas of presence	Biological characteristics
<i>Cinnamomum verum</i> , Kannel			
<i>Psidium cattleianum</i> , Guave de Chine			
<i>Adenanthera pavonina</i> , Agati			
<i>Sandoricum koetjape</i> , Santol			
<i>Alstonia macrophylla</i> , Bwa Jaune			
<i>Artocarpus heterophyllus</i> , Jackfruit			
<i>Tabebuia pallida</i> , Calice du pape			
<i>Syzygium jambos</i> , Jambrosa			
<i>Hevea brasiliensis</i> , Rubber tree			
<i>Anacardium occidentale</i> , Cashew			
<i>Paraserianthes falcataria</i> , Albizia			
<i>Dillenia suffruticosa</i> , Bwa Rouze Blan			
<i>Pentadesma butyracea</i> , Bwa Beurre			

Shrubs:

Species	Date introduced	Areas of presence	Biological characteristics
<i>Clidemia hirta</i> Faux watouk			
<i>Memecylon caeruleum</i> Bwa demon			
<i>Lantana camara</i>			
<i>Chrysobalanus icaco</i> Prune de France			
<i>Ardisia crenata</i> Christmas tree			
<i>Ardisia elliptica</i>			
<i>Leucaena leucocephala</i> Cassie			
<i>Ochna ciliata</i>			
<i>Rubus rosifolius</i>			

Others: if you included other species in your list of most problematic invasive plant species, you are asked to answer this question also for those species.

Species (Latin and vernacular name)	Date introduced	Areas of presence	Biological characteristics

C) Impacts

7. Please list the main invasive species for the following specific habitats, and their impacts (positive or negative) on the habitat:

Habitat	Species	Impacts
Intermediate Forest (Secondary Lowland Forest)		
Inselbergs (Glacis)		
Mountainous Cloud Forest		

Habitat	Species	Impacts
Other Habitats (Please specify habitat: Palm Forest, Coastal Forest, Mangroves, Coralline Islands)		

8. Do you know of possible conflicts of interest that result from the presence of the invasives? (e.g.: Cinnamon should be eradicated but creates employment)

9. Categories of impact:

In the following we have listed potential impacts of invasive plant species. Please state for each category if you know about an invasive plant species that shows the particular impact in the Seychelles. Please state if you consider the impact as positive or negative.

Please only answer these questions if the information was not already given in previous questions.

i) Change of disturbance regime:

- Fire disturbance: increases or decreases fire risk.
- Water regime: changes the water dynamics of rivers, coastal zones etc.
- Changes the water budget of a habitat.
- Erosion regime: increases or decreases erosion risk.

ii) Changes habitat conditions (e.g. mutualistic effects: the invasive species changes the habitat in a way that makes further invasion easier)

- Increases light availability on the forest ground.
- Increases / Decreases soil nutrient availability.

iii) Changes the habitat structure:

- Stops rejuvenation of native species.
- Forms thickets (monostands).
- Out-competes native species.

iv) Changes interactions between animals and plants:

- Has an impact on frugivores.
- Has an impact on herbivores.
- Has an impact on insectivores.
- Creates complex trophic interactions (e.g. invasive plant species facilitating out-competition of native birds by exotic ones).

v) Has a genetic impact (hybridization).

vi) Is a vector of diseases, pathogens (shared pathogens, parasites).

D) Management

10. Which specific management procedures have been successful in the past or are promising for the future? Where should future invasive plant species management priorities be placed? Please define the criteria that you use to evaluate the success of a management project.

11. Awareness, public involvement and education:

- How do you evaluate the relevance of projects which increase public awareness, public involvement, and education about invasive plant species?
- Do you know about planned, started, or finished projects in the Seychelles?
- What might be (potential) future projects?

12. Eradication, habitat restoration projects:

- How do you evaluate the potential of eradication, habitat restoration projects?
- Do you know about planned, started, or finished projects in the Seychelles?
- What might be (potential) future projects?

13. Precautionary measures:

- Is there any mechanism that prevents the introduction of exotic woody plant species in the Seychelles? Is it efficient?
- Is the Seychelles legislation comprehensive to avoid the introduction of invasive species?
- Is quarantine efficient in the Seychelles?
- Is law enforcement efficient as regards the introduction of exotic species? How could this be improved in the Seychelles?
- Which agency should be responsible to coordinate and handle the problem of invasive plant species in the Seychelles?

E) Literature

Please indicate literature relevant to the problem of invasive species in the Seychelles (Authors, title, publication year, journal name / publisher / publishing organization, city where it has been published, Volume, Edition).

This page can also be used for further comments or questions.

F) Participation to the Workshop

Following the collection and analysis of all questionnaires, we invite you to **a day workshop on the 3rd of December 2002 to be held from 8.00am until 4.00 pm in the training room of the Ministry of Foreign Affairs.**

The workshop will address two main topics. Topic A focuses on the ecology of invasive plant species, topic B deals with management issues. For both topics you can choose to participate in one out of two subgroups. Please indicate your preferences below. We will decide on the composition of the different subgroups on the basis of your indicated preferences, with the attempt to have groups of similar size, and by distributing members of the same agency equally among the different subgroups.

Workshops:

Topic A: Ecology of Invasive Plant Species

Subgroups:

A.1: Screening System, Characteristics of Invasive Species in the Seychelles

A.2: Impacts on Ecosystems: Interactions between Animals and Invasive Plant Species

Topic B: Management of Invasive Plant Species

Subgroups

B.1: Eradication and Restoration Projects

B.2. Agencies, Law Enforcement, Quarantine

The following people will take part at the Workshop:

Name	Organisation	Subgroups

Appendix 3: some common names of cited plants

Species name	Common name(s)
<i>Acacia</i> spp.	Acacias, Wattles
<i>Adenanthera pavonina</i>	Agati
<i>Albizia lebeck</i>	Bois noir, Siris tree
<i>Alstonia macrophylla</i>	Bois jaune
<i>Anacardium occidentale</i>	Cashew
<i>Annona squamosa</i>	Sugar apple
<i>Camellia sinensis</i>	Tea
<i>Cananga odorata</i>	Ylang-ylang
<i>Carica papaya</i>	Papaya
<i>Casuarina equisetifolia</i>	Casuarina, Filao
<i>Chrysobalanus icaco</i>	Cocoplum, Icaquier
<i>Cinnamomum verum</i>	Cinnamon
<i>Clidemia hirta</i>	Désirée
<i>Cocos nucifera</i>	Coconut
<i>Coffea</i> spp.	Coffee
<i>Eucalyptus</i> spp.	Eucalypts
<i>Fuchsia</i> spp.	Fushsias
<i>Gossypium</i> spp.	Cotton
<i>Hevea brasiliensis</i>	Rubber, Rubberwood
<i>Lantana camara</i>	Lantana
<i>Leucaena leucocephala</i>	Leucaena
<i>Ligustrum robustum</i> subsp. <i>walkeri</i>	Sri Lankan privet, Troène de Ceylan
<i>Paraserianthes falcataria</i>	Albizia
<i>Pinus</i> spp.	Pines
<i>Psidium cattleianum</i>	Cherry/Chinese/Strawberry guava, Goyavier
<i>Psidium guajava</i>	Guava
<i>Ravenala madagascariensis</i>	Traveller's tree
<i>Rubus alceifolius</i>	Giant bramble, Raisin marron
<i>Saccharum officinarum</i>	Sugar cane
<i>Sandoricum koetjape</i>	Santol
<i>Schinus terebinthifolius</i>	False pepper
<i>Spathodea campanulata</i>	Tulip tree, Tulipier du Gabon
<i>Syzygium aromaticum</i>	Clove
<i>Syzygium jambos</i>	Rose apple, Jambrosa
<i>Tabebuia pallida</i>	Calice du pape, Pink tecoma
<i>Ulex europaeus</i>	Gorse
<i>Vanilla planifolia</i>	Vanilla
<i>Vetiveria zizanioides</i>	Vetiver