African Case Study II:

Mauritius – a History of Degradation and the Beginnings of Restoration

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Introduction

Hawaii has often been cited as the 'extinction capital of the world". This "accolade" is not one to fight over but depending on criteria used Mauritius, together with its fellow Mascarene island of Rodrigues, might be a contender for this crown.

There is little doubt that insularity has contributed to making the biota of oceanic islands, such as Hawaii and the Mascarenes, very vulnerable to extinction. However, the degradation of the biota of Mauritius has not been due to insularity alone. This can be understood by reference to the human history of Mauritius, which has been that of a colonisation motivated by an ethic of exploitation with counterbalancing forces only rarely coming to the fore. Until recent decades the virtual annihilation of all of the indigenous biodiversity of Mauritius had seemed to be inevitable. However, economic and demographic trends over the last 30 years have reduced the pressure on the remaining forests of Mauritius. At the same time some exemplary conservation efforts have provided hope that the processes of degradation can be turned around. This will not be an easy task and success is far from guaranteed. The insidious impact of invasive alien species is a legacy of the species introductions that have continued almost unabated both before and since colonisation. Invasive alien species are undoubtedly the main cause of biodiversity degradation in Mauritius today. The only way to conserve the biodiversity that remains in Mauritius will be a concerted and committed programme of invasive alien species management.

This paper places the forest degradation and terrestrial species extinctions that have occurred in Mauritius in an historical context, discusses the positive and concerted conservation interventions that have occurred since the early 1970s and examines ways in which these efforts can be scaled up in order to conserve near-native ecosystems that are viable in the long run.

Location, age and endemism

Mauritius is one of the three islands in the Indian Ocean Mascarene archipelago found west of Madagascar just to the north of the tropic of Capricorn (Fig. 1.). All three islands, Mauritius and Rodrigues (both part of the Republic of Mauritius) and La Réunion (part of France) are of volcanic origin. Mauritius has been dated at about 8 million years old. Prior to the transformation that occurred on all three islands following settlement the most common climax vegetation would have been tropical forest with the exact type dependent on altitude, topography and location relative to the prevailing southeast trade winds.

Figure 1. Mauritius and the Mascarenes in the Western Indian Ocean. The Mascarenes shown within crimson line.

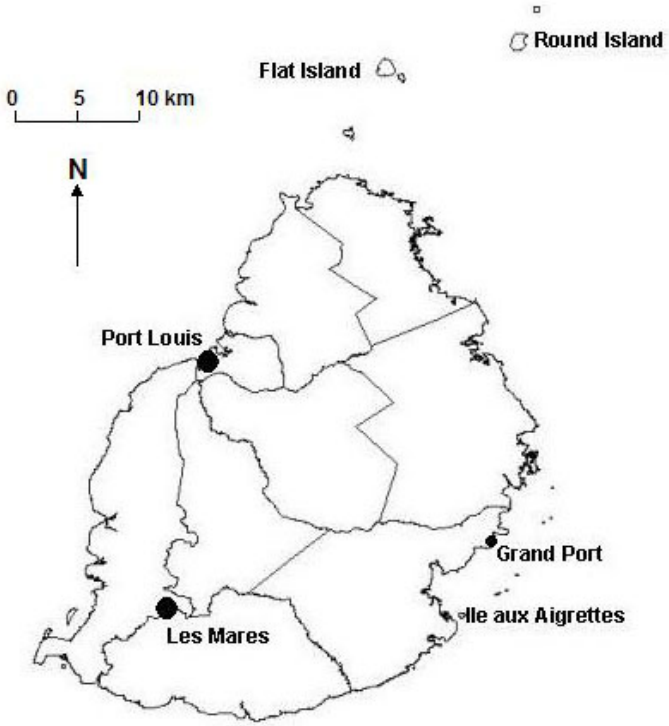

Figure 2. Map of Mauritius showing areas referred to in text. Lines on map represent district boundaries.

The age and isolation of Mauritius have combined to produce a biota with a high degree of species endemism (Table 1.), together with those typical oceanic island traits of relictualism and disharmony. Their high degree of unique species per unit area have led to the inclusion of the Mascarenes in the Madagascar and Indian Ocean Islands hotspot (Myers *et al.* 2000).

Table 1. The level of endemism of selected elements of the native land biota of the island of Mauritius. Figures include species known or thought to be extinct. Calculations are based on the assumed biota at the time it was first influenced by human activity (see text for details). The plant list includes varieties and subspecies. Snail data from Griffiths and Florens (unpublished data). Snail species include freshwater species and those that live at the land sea interface.

Endemism	Flowering plants	Landbirds	Reptiles	Land snails
Native taxa	667-681	28-31	18-20	152-157
Strict endemics	305-319 (46-47%)	18 (58-64%)	15 (75-83%)	78-79 (50-52%)
Mascarene endemics	143 (21%)	4 (13-14%)	2 (10-11%)	30-31 (19-20%)

Historical processes and the degradation of the biodiversity of Mauritius

The dramatic extinction process that has continued in all three Mascarene islands to this day began when their isolation was massively reduced the moment they came under the influence of human beings. Historical processes have helped to determine the fate of the biota of Mauritius through three phases of colonisation and 30 years of independence.

The period from discovery to colonisation and the Dutch Period in Mauritius: 1598-1710

Mauritius may have been discovered quite some time before the first known descriptions of her forests were made by the Dutch who took possession of the island in 1598 (Moree 1998). At this time Mauritius was becoming a strategically important land base between the Cape of Good Hope and the East. The island was also attracting attention for its endemic ebony *Diospyros tesselaria*, which was becoming very sought after in Europe. The increasing interest in Mauritius from several powers prompted the Dutch to occupy the island from 1638.

The initial impression the new colonists gained of Mauritius was one of abundance. The animals were easy to hunt and fish were plentiful. Van Warwijck, who led the 1598 landing, described the soil as fertile with trees that are 'so close to each other that one can hardly walk in the forest' (Brouard 1963).

Even at this time Mauritius was not pristine. Rats (*Rattus* spp.) were mentioned in 1602 and must have colonised the island before 1598, in view of the pre-colonisation extinctions discussed below. This introduction would not be surprising as many previous shipwrecks that had occurred around the island. Some major animal introductions to Mauritius are listed in Table 2. Javanese macaques (*Macaca fascicularis*) are mentioned in 1606. Cattle (*Bos taurus*), rusa or Javan deer (*Cervus timorensis*), wild pigs (*Sus scrofa*) and goats (*Capra hircus*) had been introduced to Mauritius before 1648 in order to provide food for passing sailors (Cheke 1987).

Table 2. Some of the principle introduced animal species currently feral on Mauritius that are likely to have strong negative effects on native terrestrial biodiversity (compiled from Cheke 1987, Jones 1996, Mamet 1954, Holway *et al.* 2002, Lach 2003 and Griffiths and Florens unpublished data). ? indicates doubt

Latin Name	Common name	Date of Introduction	Possible negative role
Rattus Rattus	Black rat	Before 1598	Predator of many animal groups and seeds
Macaca fascicularis	*Javanese macaque*	*Between 1598 & 1606*	*Predator of many animal groups and vegetation, alien plant seed disperser*
Sus scrofa	*Pig*	*1606*	*Predator of invertebrates and eggs on ground, disturbance of vegetation, alien plant seed disperser*
Cervus timorensis	*Rusa or Javan deer*	*1639*	*Browser of native vegetation*
Felis catus	*Cat*	*1709 or before*	*Predator of many animal groups*
Rattus norvegicus	Brown rat	1735?	Predator of many animal groups and seeds
Acridotheres tristis	Common mynah	early 1760s	Disperser of alien plant seeds, competition with native birds
Suncus murinus	Indian house shrew	c1770	Predator of invertebrates and eggs on ground
Achatina fulica	Giant African landsnail	Before 1781	*Eats native vegetation, prey source for other alien pests*
Tenrec ecaudatus	Tenrec	c1790	Predator of invertebrates and eggs on ground, alien plant seed disperser
Ptychadena mascareniensis	Frog	c1792	Predator of invertebrates and eggs on ground
Achatina panthera	Giant African landsnail	Before 1847	As above
Lycodon aulicum	Indian wolf snake	1870s	Predator of native lizards
Psittacula krameri	Rose-ringed parakeet	1886	Competitor for native birds
Pycnonotus jocosus	Red-whiskered bulbul	1892 or before	Disperser of alien plant seeds, nest predator, spider predator
Calotes versicolor	Asian garden lizard or bloodsucker	c1900	Predator of invertebrates and competitor for native reptiles
Herpestes javanicus	Lesser Indian mongoose	1900	Predator of many animal groups
Bufo gutturalis	Little toad	1922	Predator of invertebrates and eggs on ground
Pheidole megacephala	Big-headed ant	Before 1947	Displacement of native ants and other invertebrates, tending Homoptera, nectar-robbing
Anoplolepis gracilipes	Long-legged or crazy ant	Before 1954	Displacement of native ants and other invertebrates, predation on bird hatchlings, tending Homoptera, nectar-robbing
Euglandina rosea	Rosy wolfsnail	1961	Predator of native snails
Cameleo pardalis	Chameleon	before 1989	Predator of invertebrates and competitor for native reptiles
Pomacea bridgesi	Golden mystery snail	Before 1999	Currently pest on riverine vegetation with potential to expand into suitable native habitat

The dramatic effects of introduced mammals on the fauna of oceanic islands, even in the absence of significant hunting or habitat destruction, can be vividly illustrated by the fact that it is likely that between 20-25% of conspicuous vertebrate species found on the Mauritian mainland were already extinct (or at least made severely rare) from the main island before colonisation (Mauremootoo *et al.* a in press).

Ebony was selectively logged from accessible areas around the original settlement in Grand Port (Fig. 2) from which the exploitation moved to other coastal forests, with logs moved by sea to Grand Port or to Port Louis. By the final years of the Dutch occupation nearly all black ebony of commercial size had been logged from the coastal lowlands. Other species were also exploited but not on nearly the same scale (Brouard 1963). Although forest cover was little changed during the Dutch period forest composition would have been considerably altered.

The extinction process continued during the Dutch occupation. It seems likely that up to 20 % of Mauritius' large vertebrate species disappeared from the mainland during this time. Dodos were last recorded from the Mauritian mainland in 1640, only two years after colonisation (Grandidier 1903-1920), though they continued to survive on offshore islets into the 1660s (Cheke in press).

As well as extinctions it was clear that certain species, notably tortoises were becoming rare during the Dutch period (Bour 1981). Tortoises were valued for their oil and meat. Their ability to go without food and drink for several months made them ideal sources of fresh meat for sailors. As a consequence they were harvested in great quantities, thus further depleting the Mauritian population (Cheke 1987). By the end of the 17th Century tortoises had become very rare (Leguat 1708) though this was not due to hunting alone.

Most species that were hunted would have had access to plentiful refuge habitats. It, therefore, seems likely that introduced predatory mammals were the ultimate cause of most of the extinctions during this period, though hunting probably accelerated the extinction process. Alien species such as rats, cats (*Felis catus*) and monkeys, would have been formidable predators of eggs and young of animals that nested in trees while predation by pigs, introduced by the Dutch in 1606 (Pitot 1905), could have caused additional catastrophic mortality to species such as dodos, rails and tortoises that laid their eggs on the ground.

With the then-exploitable ebony largely exhausted the Dutch finally left Mauritius in 1710. In an effort to ensure that the island was not occupied by a rival power colonists were ordered to release their dogs into the forest so that they would exterminate all the island's (native and introduced) game species. Fortunately this attempted mass extinction through the release of an invasive species was unsuccessful (Barnwell 1948).

1721 – 1810: The French Period in Mauritius

The French continued the timber extraction began by the Dutch but also established the infrastructure for long-term colonisation of Mauritius and encouraged permanent settlement and agriculture. Land "Concessions" were granted to French settlers in return for the cultivation of export products such as coffee (*Coffea* species), sugar (*Saccharum officinarum*) and indigo (*Indigofera tinctoria*) and spices from the 1770s.

From the earliest days, slavery was to play a key role in the history of Mauritius. It has been estimated that 160,000 slaves were imported into the colony during the French period. Slavery allowed the expansion of plantation agriculture. By the end of the French period about a quarter of the land was cultivated under a diverse range of crops. The population had undergone a corresponding increase from 800 in 1735 to c78,000 in 1807, of whom 84 % were slaves (Toussaint 1972). This period saw the beginning of large scale clear-felling of forest for land conversion (Fig. 3)

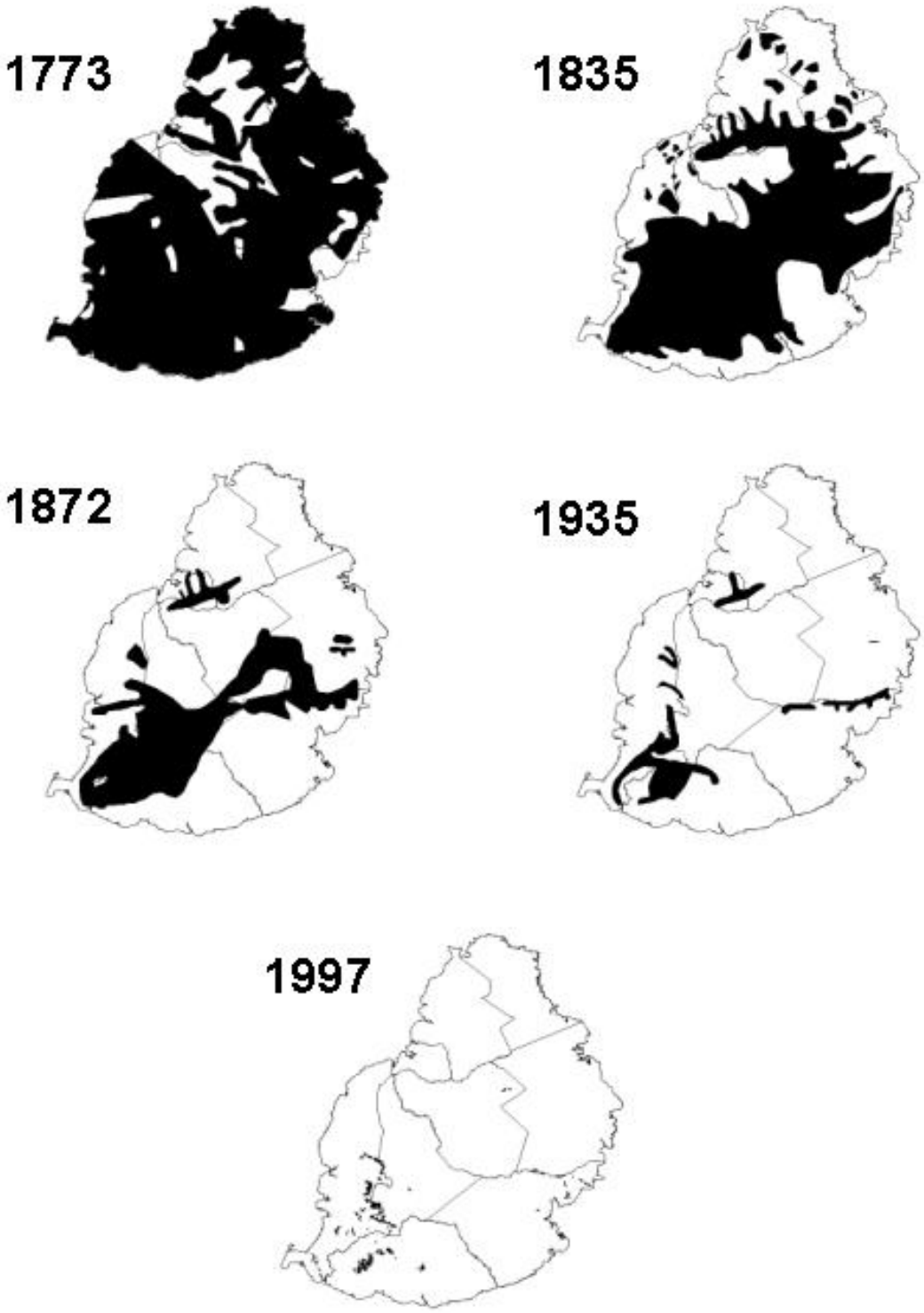

Figure 3. Areas under indigenous forest (black) in 1773 (after Desroches), 1835 (after Fraser), 1872 (after Gleadow 1904), 1935 (after Vaughan and Wiehe 1937) and 1997 (after Page and D'Argent 1997).

By the end of the French period about 35 % of the island, mostly that below the 200 m contour, had been deforested (Brouard 1963).

Hunting continued to be widespread and it is likely that it was the cause of increasing rarity of many species and the extinction others. The parrot "*Lophopsittacus bensoni*" was the only endemic large vertebrate to become extinct from Mauritius during this period. This bird was frequently hunted for food, though its extinction could have been hastened by the loss of lowland forest, as well as the impact of the existing suite of introduced predators.

The French period was a very active time for the development of botanical and acclimitisation gardens (Rouillard and Guého 1999). It was in this period that many of the alien plants, that were to become major long-term threats to Mauritius' native forests, were introduced. Some notable French introductions were Chinese guava (*Psidium cattleianum*), false acacia (*Leucaena leucocephala*) (*Ravenala madagascariensis*) (Table 3.). Flinders (1814), writing in 1806 makes reference to the colonisation of 'raspberries', probably *Rubus rosifolius* and wild tobacco (*Solanum* species) making paths impassable. It is not clear, however, how far invasion had proceeded at that stage though it had become a problem in disturbed areas.

The brown rat (*Rattus norvegicus*) and the Indian house shrew (*Suncus murinus*) were accidental introductions (Table 2) while several game bird species were deliberately introduced during the French period (Jones 1996).

Table 3. Some of the principal invasive woody and shrubby plants in Mauritius (adapted from Strahm 1999). Habitat in which these species are most aggressive is given as L lowland or U upland. Introduction dates apply to Mauritius only. ? indicates doubt.[1]from Rouillard and Guého (1999) [2]G. D'Argent (pers. comm.), [3]A.S.Cheke (pers. Comm.).

Scientific name	Common name	Habitat	Introduction Date
Syzygium jambos	Jamrosa	U	[1]1677-1692 or [3]1750s
Ravenala madagascariensis	Ravenal	U	[1]1751
Rubus alceifolius	Framboise marron	U	[1]1752 or before
Furcraea foetida	Aloes	L	[1]1754 or before
Psidium cattleianum	Chinese guava	U	[1]1763 or before
Flacourtia indica	Prune Malgache	C, L	[1]1772 or before
Lisea glutinosa	Bois d'oiseau	U	[1]1775 or before
Hiptage benghalensis	Liane cerf	L, U	[1]1785 or before
Ardisia crenata	Arbre de noel	U	[1]Around 1800
Leucaena leucocephala	(False) acacia	L	[1]1810 or before
Litsea monopetala	Yatis	U	[1]1815
Acacia nilotica	Piquant loulou	L	[1]1816 or before
Wikstroemia indica	Herbe tourterelle	L, U	[1]1828 or before
Lantana camara	Vielle fille	L	[1]1837 or before
Tabebuia pallida	Tecoma	L	[1]1860s
Schinus terebinthifolius	Poivre marron	L	[1]1863 or before
Ligustrum robustum subsp. *walkeri*	Troène, Privet	U	[1]Around 1900?
Ossaea marginata		U	[1]1930s
Clidemia hirta	Koster's curse	U	[2]1940-1950
Homalanthus populifolius		U	[2]1960-1970

1810 – 1886: The initial British Period in Mauritius

Mauritius

The British occupied Mauritius to prevent the island being used as a base from which the French could harass its commercial ships making journeys to and from the Indies.

Under the British the area under sugar cane expanded hugely. In 1810 45 km^2 was under sugar. By 1830 this area had expanded to 225 km^2. In the meantime the population had increased to 100,000 (Cheke 1987).

From the 1830s the rate of forest clearance accelerated for a combination of reasons: Sugar production was boosted by the removal of a discriminatory tax on sugar on the London market in 1825 (Toussaint 1973); there was increasing demand for wood for steam-powered sugar mills and slavery was fully abolished in 1839. A minority of former slaves set up shifting cultivation systems in areas of forest (Bissoondoyal and Servansing 1989) adding to forest degradation.

A system of importation of indentured labour from India was established in order to increase the labour supply following the abolition of slavery. For most of the period of indentured labour the importation rate was deliberately kept high in order to suppress wage competition and therefore keep labour costs low. This policy, together with periods of high sugar prices led to periods of extremely high labour importation, peaking in 1859, during which year 44,000 Indians were imported to Mauritius (Addison & Hazareesingh 1984). The population of Mauritius tripled from 100,000 in 1830 to 300,000 in 1860 with Indians becoming the majority racial group in the 1850s. The rapidly increasing population helped cause a huge increase in demand for fuel wood (Brouard 1963). Other pressures for forest clearance included the opening of railways using wood-burning locomotives from 1864 and 1865 and the mass settlement of higher altitude areas on the Mauritian central plateau following malaria epidemics of 1865-68 (Mamet 1979). This in turn led to an increasing use of plateau areas for sugar cane cultivation.

As a consequence of these processes only about 3.9 % of the Mauritian mainland was under good canopy native forest by 1880, 8.5 % was under native forest and degraded native forest and 17 % under forest of any kind (Thompson 1880).

The Mauritius owl (*Mascarenotus commersoni*), blue pigeon (*Alectroenas nitidissima*) and the fruitbat (*Pteropus subniger*) all became extinct during this period, the last three large vertebrate extinctions to date from the Mauritian mainland.

Historical accounts indicate that from the mid-19th century that many native forest areas in Mauritius underwent a dieback process possibly due to an insect borne pathogen (Cheke and Hume in prep.). One of the consequences of the mass dieback of native trees was their replacement by invasive species (Newton 1863). Although invasive alien species had been commented upon during the French period their prevalence in areas of native forest was far more frequently documented from the mid-nineteenth century. Many of the plants species that are currently the most problematic for Mauritian native forests were well established in Mauritius' forests during this period.

Species introductions, whether by organised acclimitisation societies, on an ad hoc basis or accidental continued under the British. Among the plant species introduced during this period those that would become serious invaders were Vielle fille (*Lantana camara*), privet (*Ligustrum robustum* subsp. *walkeri*) and piquant loulou (*Acacia nilotica* subsp. *Adstringens*) (Table 3.). Animal introductions under the British during this period were mostly of gamebirds. Amongst the pest animal species introduced during this period were the giant African landsnail (*Achatina fulica*) some time in the mid-late eighteenth century and the Indian wolf snake (*Lycodon aulicum*), which was well established by the late 1870s.

From the 1850s onwards concern about the negative impacts of deforestation motivated legislation and forest-related publications that appeared with particular frequency in the years between 1872 and 1883 (Brouard 1963). Though there was not always a consensus among decision makers on the role of the forests in Mauritius there was a general feeling that they aided water supply. In addition it was felt by many that malaria was a direct consequence of deforestation (Brouard 1963). It is likely that this misapprehension helped to maintain some forest cover in Mauritius during this period. In spite of considerable pressures the incessant clearing of native forests considerably slowed down in the 1880s

1886 - 1968: The later British period in Mauritius

A slow down in the rate of importation of indentured labour until its abolition in 1923 and the continued effects of disease epidemics considerably reduced the rate of population increase in Mauritius up to 1944 when her population stood at 431,070. Nevertheless, this still represented a very high population density. The continued demands of the sugar industry upon which the economy of Mauritius depended meant there was still a great pressure to clear more forest.

Privet was widely planted from 1902 and spread rapidly with the help of a suite of seed dispersers notably the red-whiskered bulbul (*Pycnonotus jocosus*). Privet was introduced to fill in gaps in forest areas and to combat the

invasion of the other species of wild raspberry (*Rubus alceifolius*) (Rouillard and Guého 1999). In this respect the widespread planting of privet qualifies for inclusion in the list of naïve biological control attempts.

A more widely documented example of naïve biological control was the introduction of the lesser Indian mongoose (*Herpestes javanicus*) in 1900 in an effort to control rats. The mongoose has been implicated in the local extinction of Audubon's shearwater (*Puffinus lherminieri*) (Cheke 1987), four species of introduced gamebird (Carié 1916, Jones 1996) and possibly in the increasing rarity of the endemic pink pigeon (*Columba mayeri*) (Roy 2002).

In 1911 the cane grub *Phytalus* (=*Clemora*) *smithii* became a serious pest of sugar cane. In response the little toad *Bufo gutturalis* was introduced from South Africa in 1922 (Greathead 1971). The introduced toad, which is now widespread, is thought to feed extensively on native landsnails and may be one of the reasons for their increasing rarity (Griffiths 1996). The cane toad (*Bufo marinus*), now a well known invasive species notably in Australia (Covacevich and Archer 1970) was introduced to Mauritius on at least two occasions but failed to establish (Greathead 1971).

The consequences of the fight against malaria were by no means all positive for the biodiversity of Mauritius. Marsh drainage and in-filling efforts accelerated from 1908 and continued up to c1960 (Mamet 1979) by which time large areas of inland marsh and coastal wetland had been lost.

Ironically if not for the use of DDT after the Second World War it is likely that even more marsh and wetland areas would have disappeared. Malaria was under control by the early 1950s and declared eradicated in 1973 (Roberts 2002). Prophylactic use of DDT continued into the early 1970s. The bioaccumulative effects of DDT nearly caused the extinction of the Mauritius kestrel (Jones *et al.* 1994).

From the 1950s areas were allocated for the production of tea (*Camellia sinensis*), food crop production and experimental fodder plantations. The area under tea peaked at over 4, 000 ha in 1971 (Anon 1971). Although the areas cleared were generally degraded the loss of this forest must have contributed to the increasing rarity of the native plant and animal species found in Mauritian forest fragments.

The rate of population growth in Mauritius considerably increased as malaria was brought under control in 1950s. By 1960 a high and rapidly increasing population density was exacerbating an already weak economic situation.

Independence to the present day

Mauritius became independent in 1968 as a very poor country with an economy dependent on sugar, a population that was already one of the densest in the world and growing at an exponential rate and a very high rate of unemployment. Some pre-independence studies had pointed to a worse case scenario of 3 million people living in abject poverty by 2003 (Titmuss and Abel Smith 1961).

Economic development and job-creation was the priority of this newly independent nation. In 1971 a World Bank financed job-creation programme "Travail Pour Tous" (work for everybody) was initiated for the clearance of 'scrub' and its replacement with pine (Anon 1971). The programme continued until about 1980 with some forest clearance still going on in certain areas. However, the most intensive period of forest destruction finished in 1975 by which time over 2,000 ha of good quality and degraded forest had been cleared

The clearance of the c500 ha of forest at Les Mares was particularly serious. This area was suitable habitat for pink pigeons, Mauritius fodies (*Foudia rubra*), olive white eyes (*Zosterops chloronothos*) and paradise flycatchers (*Terpsiphone bourbonnensis*), possibly because its marshy nature deterred predators. It is likely that many native plant species, notably in the genus *Pandanus*, were also made increasingly rare through this short but intense programme.

The "Mauritius economic miracle" that has seen consistent economic growth of 5% or more over the last thirty years of the 20th Century has been widely documented. (e.g. Lamusse 1985, Bowman 1991 and Dommen and Dommen 1999). From the late 1960s, socio-economic development in Mauritius began to move away from agriculture in general and sugar in particular. The setting up of the Export Processing Zone (EPZ) in the early 1970s led to an increase in industrial employment. Tourism emerged as the 'Third Pillar' of the economy and the financial services and information technology sectors are currently being developed in moves to further diversify the economy.

It is almost certain that economic development saved the little native forest that remained in Mauritius as the imperative to use these marginal areas for extractive activities declined. There is currently very little forest clearance

although the remaining remnants of forest are degrading rapidly because of the effects of invasive alien species in the majority of areas in which there is no active ecosystem management (Fig 3.).

A recent study of woody plant abundance in an area of upland forest originally censused in 1939 (Vaughan and Wiehe 1941, Mauremootoo *et al.* unpublished data) shows a dramatic decline in native tree abundance with shrub, small tree and large tree abundance decreasing by c.70% in a c.60 year period. The fate of seedlings and saplings was even worse with percentage declines of over 99%.

Species introductions if anything accelerated in the post-colonial era. Recent naturalisations with potentially destructive ecological effects include the chameleon (*Chameleo pardalis*) and the golden apple mystery snail (*Pomacea bridgesi*). Reliable information has yet to be compiled on plant introduction levels but they too are likely to be increasing. A recent study on Insect species introductions to Mauritius shows that these have accelerated considerably in the late 20th century (Williams and Ganeshan 2001). Of the 22 significant pests that entered Mauritius over the century 14 have arrived since 1975.

The development of current conservation approaches in Mauritius

The development of terrestrial conservation work in Mauritius since 1973 has been a story of fruitful national and international collaboration. The international appreciation of the urgency of the Mauritian situation was heightened by the visit of Sir Peter Scott to Mauritius in 1973.

International efforts resulted in a species recovery programme to save the Mauritius kestrel from 1973 (Diamond 1987). The eventual success of the kestrel programme has acted as a flagship around which to rally support for other species and ecosystem conservation initiatives.

Durrell Wildlife Conservation Trust that has consistently supported conservation in Mauritius since 1976 (Jones and Hartley 1995) is particularly worthy of mention as an example of the value of a long term commitment to conservation programmes, which can rarely be completed in the short time periods to which funding is often constrained. Concrete support from the Mauritian Government came very soon after the kestrel programme was initiated with the building of a captive rearing centre in 1976 (Jones and Hartley 1995). Government staff numbers working on conservation projects have increased from a single individual in 1978 to over one hundred in 2003. There has been an accompanying increase in staffing levels of the Mauritian Wildlife Foundation, the leading conservation NGO in Mauritius and Rodrigues from less than ten in 1984 to over 70 in 2003.

Current conservation efforts in Mauritius centre around three linked approaches, species recovery programmes, ecosystem restoration on the mainland and islet ecosystem restoration. These approaches are summarised below. More detailed account can be found in Mauremootoo and Towner-Mauremootoo (in press) and Mauremootoo *et al.* b (in press).

Species Recovery Programmes

The species recovery programme for the Mauritius kestrel in the early 1970s (Jones *et al.* 1994) expanded into the pink pigeon and echo parakeet (*Psittacula eques echo*) species recovery programmes. Rare plant species recovery work began in the early 1980s.

At the core of each species recovery programme is the investment of as much effort as is practically possible to enhance the survival success of each individual of the endangered species in question. This is in order to maximise species survival and genetic conservation by representing as many founders as possible and minimising the time the population spends in a genetic bottleneck.

Intensive management has helped the kestrel to reach a population of over 500 birds; a healthy population size for an island raptor. The Mauritius kestrel is now considered to have been saved from extinction (Jones, pers. comm.). The pink pigeon and echo parakeet had wild populations of over 300 and c.170 birds in 2003 up from their lowest levels of 13 and c.20 birds respectively in the wild. Both species are on their way to safety, although their populations still require intensive management.

The intensification of plant species recovery efforts in Mauritius and Rodrigues in recent years has resulted in the propagation of over 230 species of native plants, most of which are endangered. In some cases species have been propagated and reintroduced into the wild in great numbers. A notable example of this is the Mandrinette *Hibiscus liliiflorus* a Rodriguan endemic recently known from only three individuals in the wild. To date over 1000 individuals of this species have been planted in protected areas that are being actively restored (Mauremootoo and Payendee 2002).

Mainland ecosystem restoration

Mainland restoration essentially comprises of two main approaches, that undertaken in 'Conservation Management Areas' (CMAs) and 'active' restoration. CMAs are small plots that are fenced to keep out deer and pigs and weeded of introduced plants. Work of this kind had been initiated before the bird species recovery programmes began but the major phase of expansion of these efforts date from the mid 1980s with the work led by Wendy Strahm (Strahm 1994). CMA sites are located in areas with relatively intact native canopies. The existing native trees provide seed sources for enhanced regeneration once weeding is underway. Currently about 45 ha of forest in ten plots have been weeded and fenced. The effectiveness of CMA management for the conservation of different components of Mauritian biodiversity is summarised in Mauremootoo and Towner-Mauremootoo (in press).

CMA work is labour intensive and costly. The annual labour cost for maintenance weeding of CMAs in 2001 was estimated at $143/ha per year (Mauremootoo *et al.* b in press)

Some restoration sites have become so degraded that weeding alone is only likely to provide the conditions for the huge weed seedbed to germinate and rapidly choke the area with weeds once again. These "actively restored" areas are weeded and native pioneer plants are planted in the site in order to accelerate secondary succession to a native forest. Fencing is also carried out if necessary.

It may seem strange that such invaded sites would be chosen as restoration areas. They are chosen because they contain some very endangered plant and animal species (e.g. Grande Montagne in Rodrigues), because they form a part of an otherwise fairly well conserved ecosystem (e.g. certain parts of Ile aux Aigrettes) or because the area is part of a small island which, in the long term may be restored to an almost completely native cover with minimum reinvasion from alien seed sources (e.g. Flat Island, not yet managed but a key area for future restoration work).

So far the focus of active restoration of extremely degraded areas has been in the two mainland nature reserves of Rodrigues (Grande Montagne and Anse Quitor) and on Ile aux Aigrettes. Intensive restoration of extremely degraded areas of Round Island has been started recently. So far about 50 ha in Mauritius and Rodrigues has been managed in this way

Islet Restoration

Mauritius is fortunate to be surrounded by more than 20 islets. Such islets have great conservation potential because their small size and sea barrier makes it possible to eradicate certain introduced species, notably introduced mammals. Cats, rabbits, rats, and goats are among the mammals that have been eradicated islets off Mauritius and Rodrigues (Bell 2002).

Unfortunately even after eradication of mammals these islets are usually in need of active restoration. After the eradication of goats and rabbits pilot restoration activities on Round Island were carried out periodically from the early 1980s to mid 2002 after which major acceleration of the intensive restoration of Round Island vegetation started. Most major initial weeding and planting work has been completed on Ile aux Aigrettes following the eradication of rats.

The Challenges of large scale restoration

The conservation achievements in Mauritius over the past few decades have been considerable. However we are still only conserving a very small proportion of the areas that have restoration potential. Currently only 18% of the area of islets that have high restoration potential is being actively restored. The equivalent figure for the mainland is only 2%. This represents only about 0.04% of the area of Mauritius.

It is highly likely that the size of the areas currently managed is insufficient for sustainable conservation. If non-managed areas were not degrading we would have more time to act. Unfortunately if present trends continue our efforts will result in small oases of native forest in a sea of introduced species. It is very likely that if this scenario prevails species such as pink pigeons and echo parakeet will have to be intensively managed indefinitely if they are to survive "in the wild". This conjures up images of zoos and gardens as the future for the much of the native terrestrial biodiversity of Mauritius.

This is not an outcome desired by any conservationist. The question is not if we should scale up the level of ecosystem restoration in Mauritius but how can we do this in a way that does not jeopardise our achievement so far and is technically and financially sustainable.

This involves efforts in three key areas. There must be technical improvements, improved institutional functioning and conservation concerns must be mainstreamed. Key technical improvements are summarised below as are possible methods of mainstreaming. Institutional challenges are not discussed in this paper but are considered in detail in Mauremootoo *et al.* b (in press).

Technical improvements

A summary of the types of technical improvements that can be made in order to scale up conservation in Mauritius is given below:

Larger scale predator management

Current predator management work in Mauritius is only carried out at most at the scale of tens of hectares. Recent work in New Zealand 'mainland islands' has indicated that it is possible to maintain a suite of predators at very low densities in areas of more than 1000 ha (Saunders 2000).

Costs are likely to be high but they would be lower in Mauritius than in New Zealand because of relative labour costs. There also exists the potential for cost recovery by granting concessions for deer and pig hunting

Rationalisation of weed management

Initial weeding costs can be halved by replacing manual uprooting with cut stump herbicide application (Mauremootoo *et al.* unpublished data). Maintenance weeding costs can also be reduced. Observations indicate that it is not necessary to weed most CMAs nearly so frequently as is currently the case following the initial reduction of the high residual levels of weed seed in the soil seed bank. Maintenance weeding can be further rationalised by concentrating on removal of species that represent a threat to native species regeneration, rather than removing every non-native plant in order to produce a 'clean' plot.

The use of integrated and responsive management in place of prescribed hand-weeding operations would result in considerable economies in CMA management. The same kind of increases in efficiencies that have been made on Ile aux Aigrettes in recent years (Newfield *et al.* 2003) could cut CMA weed management costs to an estimated one–quarter of their current levels (Mauremootoo unpublished data).

It is likely that integrating large-scale vegetation and vertebrate pest management will result in positive synergies that will reduce management costs. Large-scale predator control can considerably reduce the need for fencing. Rat and monkey management is likely to increase the regeneration rate of many native plants which should in turn hasten the speed of native vegetation recovery, therefore reducing long term weed management costs.

The use of grazers and other novel techniques

Other ways of increasing the scale of restoration are likely to bring cost reductions. The potential for using fire and grazers as weed management tools has been detailed by Mauremootoo and Towner-Mauremootoo (2002). Recently the idea of using of animals such as Indian elephants as a cost-effective means of clearing large tracts of non-native vegetation has been mooted (R. Gibson pers. comm.). The most likely design for integrated large-scale ecosystem restoration programmes for Mauritius and Rodrigues would be a combination of novel cost-reducing tools with a fine-tuning of current methods. Mauremootoo and Towner-Mauremootoo (2002) articulated a generic scheme for integrated large-scale restoration in the Mauritian context. A key element in this scheme was the reduction of weed seed bank levels following initial weeding by the use of grazing animals. This will inevitably mean low levels of native regeneration in the first few years following initial weeding but it is envisaged that subsequent native regeneration will be more effective once weed seedbank levels are reduced and restoration areas are sufficiently large to minimise the impact of weed seed rain from neighbouring weed reservoirs.

It is not envisaged that the process outlined above will become a formula for all restoration areas. Formulaic thinking has in many cases made restoration management in Mauritius inflexible and unresponsive. Instead herbicides, grazers, fire and other methods must be thought of as tools to be used as part of an integrated process. Exact management prescriptions will be dependent on the specificities of the managed areas and responsive to ecosystem changes as indicated by regular monitoring and the processing of the results of this monitoring.

Biological control

Biological control has been frequently advanced as a means of making vegetation management sustainable in Mauritius (Lorence and Sussman 1988, Strahm 1994, 1999, Fowler *et al.* 2000, Mauremootoo and Towner Mauremootoo 2002). Unfortunately biocontrol programmes for most of the problem weeds of Mauritius and Rodrigues have yet to be developed and developing a weed biological programme in its from scratch is expensive, estimated at an average of $1 million at 1976 costs (Harley *et al.* 1992). Even given the assumption of complete success (which is unlikely) a targeted programme beginning with the worst weeds may not greatly aid ecosystem restoration in the short term as the weed species that were controlled may only be replaced by others that could be

equally problematic; the so-called Sisyphus effect (Mack and Lonsdale 2002). However, it is possible that senescing weeds under a biocontrol programme may act as nurse plants beneath which native regeneration can take place in sites with significant native species seed sources (S.V. Fowler pers. Comm.).

Even with the caveats outlined above some single species biological control programmes could result in significant ecosystem benefits even if the issues of other introduced weeds were not dealt with simultaneously. Chinese guava, a significant ecosystem transformer (Mauremootoo *et al.* c in press) is one such example. Another is wild raspberry, a highly efficient gap-coloniser which, by virtue of its thorns, is a nuisance weed and difficult to manage manually.

Mainstreaming

Even with improved techniques it is likely that increased funding will be required if conservation is to reach the required scale. The required finances are only likely to accrue if conservation considerations are incorporated into mainstream concerns. Possible ways to help mainstream conservation efforts in Mauritius are listed below:

Community conservation

This is not in itself a financing mechanism but work undertaken by the local community can increase the amount of conservation work achieved. It is also an excellent way of increasing awareness.

Use of volunteers

This is increasing in both Mauritius and Rodrigues. With increased affluence an awareness volunteers are likely to become increasingly important.

Promoting conservation projects with clear socio-economic benefits

The efficacy of integrating conservation work into wider societal aims has been demonstrated by the South African Working for Water project (Van Wilgen *et al.* 1998). In this instance employment generation, local empowerment and water provision have fuelled the world's largest alien species control programme. Of course the exact nature of any such scheme depends on the specificities of the area under consideration. Rodrigues is in many ways in an analogous situation to South Africa with high unemployment, water-demanding invasive alien species in watersheds and a severe lack of water. In addition there is acute over-fishing and the need for provision of alternative employment for fishers. A great deal could be achieved by adopting a Working for Water style programme in Rodrigues.

In Mauritius the situation is not analogous to that in South Africa. However, restoration work could achieve important societal benefits in Mauritius as well. The sugar sector in Mauritius is currently shedding a lot of labour. Most of these redundant workers are unlikely to be able to find jobs in the high technology sectors that Mauritius is currently promoting as part of her development strategy. However, ex sugar estate labourers as well as others from declining sectors such as fisheries could be employed in restoration work.

Widening the tax base for conservation

Mauritius currently raises money for conservation through a tax on monkeys exported for biomedical work and for conservation and environmental protection in general through a tax on tourism and on some other potentially environmentally-damaging activities (Mauremootoo *et al.* d in press). It is likely that tax levels could be raised to increase revenue for conservation. However, this would need to be accompanied by a concerted awareness-raising programme to create a wider support base for conservation than that currently prevailing in Mauritius.

Ecotourism

Ecotourism has in many cases been seen as the main way in which the native biodiversity of Mauritius can become a direct source of revenue to the country. However, ecotourism alone is unlikely to be a panacea and must be seen as part of an integrated conservation strategy.

Currently sugar estates are managing their forest land for a variety of remunerative activities including those that have been marketed as ecotourism; jeep 'safaris' on trails through aesthetically appealing forests dominated by introduced species such as acacias, aloes (*Furcraea foetida*) and liane cerf (*Hiptage benghalensis*) with other marketed attractions including introduced deer, pigs (*Sus scrofa*) and game birds. It is likely that a tour of a restored Mauritian forest, whether on private land or in State protected areas, would attract more tourists than the tours currently on offer. However, the increased numbers are unlikely to be considerable as the current tropical forest appears "authentic" to the majority of tourists who have no specialist knowledge. Increased demand for tours of a restored forest would have to be considerable if tourism alone were to finance the difference between the costs of restoration and current management. If restoration programmes were to be adopted in such areas it is therefore likely that the Mauritian Government or outside agencies would have to find this incremental cost above that which could be raised by private operators alone.

Discussion: Past, present and future?

The terrestrial biodiversity of Mauritius has been blighted by the impact of invasive alien species. However, their impact can only be understood in an historical context. It is certain that the dramatic levels of forest destruction and fragmentation that accompanied species introductions have magnified the effects of alien species.

The example of Mauritius is a clear illustration, if ever it were needed, that in the case of forest degradation prevention is better than cure. Unfortunately for Mauritian terrestrial biodiversity it is a cure in the form of ecological restoration that is needed and that has been the line that has been pursued.

After about 25 years of hands-on conservation in Mauritius we can summarise some of our major achievements as follows:

- We have saved many of our most endangered plant and vertebrate species from the brink of extinction
- We can propagate most of the endangered plant species of Mauritius and Rodrigues
- We can probably save most of our remaining endangered species from the brink of extinction, given sufficient resources
- We can restore Mauritian forest ecosystems to something approaching their former state in a relatively short period of time through intensive restoration programmes
- Conservation capacity in Mauritius has increased hugely in recent years
- Mauritius has provided examples of successful conservation efforts, which have inspired others in similar 'desperate' circumstances to believe that success is possible

Considering the doleful scenarios of not much more than three decades ago these represent considerable achievements. The challenge is now time to go to the next stage in conservation. Only by scaling up our efforts will we secure the future of our terrestrial native biodiversity. Given Mauritius' record to date of defying the odds, a successful response to the challenge of large-scale restoration seems eminently possible.

Acknowledgements

I would like to thank the IUCN for funding my attendance at the World Parks Congress. Much of the work summarised in this paper has been made possible by staff and volunteers of the Mauritian Wildlife Foundation, the National Parks and Conservation Service and the Mauritius and Rodrigues Forestry Service. A great deal of material for this paper was provided by, among others, the following: Anthony Cheke, Arnaud Meunier, Carl Jones, Clare Towner-Mauremootoo, Jean-Claude Sevathian, Nigel Richards, Rachel Atkinson, Richard Payendee, Vincent Florens, Vishnu Bachraz and Yousoof Mungroo.

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