INVASIVE ALIEN PLANTS AND THEIR MANAGEMENT IN AFRICA

Gordon Boy & Arne Witt

HOW A MULTI-COUNTRY 'WAR ON WEEDS' PROJECT IS HELPING AN INFESTED CONTINENT TO STEM THE COLONISING ONSLAUGHT OF INVASIVE SPECIES

Gordon Boy is a freelance writer, reporter and editor who specialises in topics relating to natural history, the environment and conservation. Born in Kitale, in western Kenya, he has travelled widely in sub-Saharan Africa, as a journalist. His first book, *Snowcaps on the Equator*, published in London in 1989, was about the mountains of East and Central Africa.

Since then, hundreds of his articles and features have been published in magazines, and for eight years (2000–2008) he was the Editor of *Swara* – the quarterly journal of the East African Wild Life Society.

More recently, he has produced a number of acclaimed natural history and ecology guidebooks, while also writing and editing scientific and project reports for global environment and conservation agencies. He now lives in Nairobi.

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Prior to joining CABI Africa, Witt worked in South Africa as a Senior Researcher and Division Manager for the Plant Protection Research Institute of the Agricultural Research Council (ARC-PPRI). He has extensive experience researching the biological control of invasive alien species, particularly plants.

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INVASIVE ALIEN PLANTS AND THEIR MANAGEMENT IN AFRICA

Synthesis Report of the UNEP/GEF **Removing Barriers to Invasive Plant Management in Africa (RBIPMA) Project**, implemented in four African countries (Ethiopia, Ghana, Uganda and Zambia) between 2005 and 2010

By Gordon Boy

Co-author Arne Witt

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FOREWORD

THE introduction of species to new environments outside of their natural home ranges carries significant risks. Invasive alien species are major drivers of biodiversity loss. As such, their continuing spread is undermining the ecological, social and economic well-being of entire regions. They can also cause serious disease outbreaks, including diseases affecting humans. Through its Article 8(h), the Convention on Biological Diversity holds that each Contracting Party shall, as far as possible, and as appropriate, prevent the introduction of, and/or control, or eradicate, those alien species which are known to threaten ecosystems, habitats, or species. In adopting the Strategic Plan for Biodiversity 2011–2020, Parties to the Convention made the following commitment: "By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment."

Invasive Alien Plants and their Management in Africa is the story of an important UNEP/GEF initiative aimed at helping the nations of sub-Saharan Africa to honour their contractual obligations, as Parties to the Convention on Biological Diversity, to address the increasingly dire impacts – ecological, social, and economic – of alien plant invasions. In providing a detailed record of the lessons learned from the experiences of the *Removing Barriers to Invasive Plant Management in Africa* Project, carried out between 2005 and 2010 in four African countries, this book has potentially far-reaching implications for the planning and implementation of other, forthcoming initiatives in this field, both elsewhere in Africa and across the developing world.

The book reveals just how devastating the impacts of biological invasions can be, while showing how enhanced capacity is essential, if effective long-term measures are to be instituted to manage invasive alien plant species and their impacts. We are left in no doubt that redoubled levels of international commitment and collaboration, coupled with the allocation of significantly greater financial resources, are going to be needed, if countries in Africa are to succeed in building on the gains of invasive alien species' management activities already under way on the continent.

While the issue of invasive alien species is clearly global in scope, it is imperative that concrete measures be taken nationally. Effective national policies and instruments, including enforced legislation regulating and managing invasive alien species, provide a critical basis for enabling stakeholders to join forces in preventing the introduction of invasive alien species and in managing and controlling the many threats posed by such species.

In particular, the authors of Invasive Alien Plants and their Management in Africa are to be congratulated for presenting such a thorough and accessible analysis of what has become one of the most pressing challenges of our age. Dr Arne Witt, Coordinator of the *Removing Barriers to Invasive Plant Management in Africa* Project, and experts at CABI Africa, along with the national governments of the four participating African countries (Ethiopia, Ghana, Uganda and Zambia) and all the stakeholders within each of these nations who have been involved in the project are to be commended for their application. Their findings deserve to be shared widely, so that we might draw lessons on how, at all levels, the threat posed by invasive alien species can be more effectively addressed.

Braulio Ferreira de Souza Dias, Executive Secretary, Secretariat of the Convention on Biological Diversity

FOREWORD

Invasive Alien Species (IAS) pose one of the most significant threats to biodiversity, agriculture, sustainable economic development and human and animal health on this planet. As a result of increased global trade and travel, invasive species have established themselves on every continent – not even Antarctica has escaped the onslaught of invasive plants and animals! Diverse habitats such as snow-capped mountains, deserts, tropical forests, wetlands, savannas, grasslands and marine environments are all being impacted by a range of introduced species. People living in developing countries often bear the brunt of these plant and animal invasions, as most of them are directly dependent on the natural resource base for their survival.

As such, *Removing Barriers to Invasive Plant Management in Africa* is a timely and important book as it highlights the impacts of IAS and the barriers which need to be, and can be, overcome in the fight against this global scourge. The book, covering the outputs and outcomes of a UNEP/GEF project, makes it abundantly clear that IAS are not only having an impact on biodiversity in Africa, but are also reducing, amongst a host of others, water resources, crop yields, pasture production, and hydro-electricity generation capacity together with having a significant negative impact on human and animal health. This is particularly disturbing in a continent which is already facing a large burden in the form of climate change and where food security to a large extent has yet to be achieved.

Fortunately, as the authors righty indicate, it is not all "doom and gloom" – there are solutions that can develop/strengthen IAS policies, build capacity, and create awareness to enable us to implement long-term and sustainable IAS management strategies. Given the severe loss of habitats, loss of productivity, and the resulting costs to local and regional economies, it is imperative that national governments invest significant resources in IAS management; foster cooperation between all national stakeholders, because this after all, is a cross-cutting issue; and work towards regional collaboration in fighting IAS because IAS don't respect national borders. The first step to this is working on greatly enhancing the awareness and integrating the costs of invasive species in national accounts – such as, for example, supported through natural capital accounting programs such as TEEB (The Economics of Ecosystem Services and Biodiversity).

The report presents information on IAS in a way which makes the problem easy to understand. All of those involved in the project, from GEF as the donor, UNEP as the Implementing Agency, CABI as the Executing Agency, ably assisted by IUCN, and the National Executing Agencies in Ethiopia, Ghana, Uganda and Zambia should be commended for further clarifying this complex issue.

Ibrahim Thiaw, Director, Division of Environmental Policy Implementation (DEPI), United Nations Environment Programme (UNEP), Kenya

ACKNOWLEDGEMENTS

This project would not have been possible without the contributions of many people and organisations over a period of almost eight years. It would be hard to acknowledge the contributions made by every individual and by every organisation or institution. All, though, can rest assured that we are deeply grateful for their inputs into what has been massive team effort to confront the menace in Africa of Invasive Alien Species (IAS).

The idea of a multi-country IAS project in Africa was hatched in the early years of this century in response to anecdotal reports from national governments, individuals and agencies warning of a “new crisis” unfolding on the continent, whereby wild habitats and precious natural resources, as well as farmlands and grazing pastures, were “being overrun” – leaving farming communities, pastoralists and conservation managers across Africa “in despair” over what to do. The cause of all this alarm was of course the spread of invasive plant species.

The extent of the threat posed by invasive alien plants in Africa was raised during a Phase-One Synthesis Meeting of the Global Invasive Species Programme (GISP) held in 2000 in Cape Town, South Africa, as an issue requiring urgent attention. That wake-up call led directly to the drawing up of this project. By then, it was clear that most sub-Saharan African governments had neither the capacity nor the resources to honour their contractual obligations under the Convention on Biological Diversity (CBD) to protect their natural environments from the ravages of invasive alien species. Something, then, had to be done. And so this project was born.

The project’s subsequent success has been due largely to the commitment of a core of dedicated professionals. Above all, we should like to thank the staff of the Division of Environmental Policy Implementation (DEPI) at the United Nations Environment Programme (UNEP) for their support. In particular, we are grateful to Mark Zimsky, for his guidance during the preparation phase, and to Max Zieren, who was also involved in developing the project, and who – as UNEP Task Manager – provided valuable insights and guidance during the implementation phase. Max has long been unwavering in his support for redoubled IAS management efforts globally, and has played a pivotal role in making this project a success.

Staff from the Executing Agency CAB International (CABI), too, were instrumental in developing the project – none more so than Sarah Simons, who as the past GISP Executive Director has done more than most to raise the global profile of IAS. John Mauremootoo, as the initial International Project Coordinator (IPC), also made a telling contribution, until he had to resign under unfortunate circumstances. Dennis Rangi, meanwhile, was instrumental in eliciting co-funding from the governments of the participating nations – in keeping with his strong belief that African governments must play their part in allocating resources to IAS management, rather than expect others to do so for them. Morris Akiri assisted with the development of the project, especially with regard to financial matters. Roger Day, as Acting IPC for a time, had the uncanny knack of being able to find solutions for even seemingly insurmountable problems. Florence Chege, the eternal optimist, had us all believing that African countries would indeed rise to the challenges of IAS management. Tom Owaga and the rest of the CABI administrative staff performed wonders in making sure that budgets were all completed accurately and on time, while Duncan Chacha ensured that project participants in Nairobi on project business always had a place to stay and never went hungry.

The real driving force, however, behind almost every aspect of this project – from its detailed planning and implementation to the application of sound technical approaches, and from raising IAS awareness to boosting local IAS management capacity – has to be Arne Witt, full-time IPC since joining CABI in 2007. Arne's expertise and passion has raised the profile of the IAS threat and its control among communities and governments throughout Africa and beyond, as well as among leading international organisations. His tireless commitment is redolent of that of other great environmentalists, such as Rachel Carson (of Silent Spring fame), Chico Mendes (Save the Amazon Forests), and Wangari Maathai, who famously declared, "It is important to nurture new ideas and initiatives which can make a difference for Africa".

Support from Geoffrey Howard and from Esther Abonyo, both with the IUCN, has contributed enormously to the project's success. Geoffrey is a leading authority of long standing on IAS and biodiversity in Africa, and he was in many ways as the mentor of this project. Without him, and without Arne's drive, the project might never have been able to extend its reach to so many people in Africa from so many different walks of life, under conditions that at times were extremely difficult and testing.

The contributions made by staff from the four National Executing Agencies (NEAs) – the Ethiopia Institute of Agricultural Research; the Centre for Scientific and Industrial Research in Ghana; the National Agricultural Research Organisation in Uganda, and the Environmental Council of Zambia – were key to the success of the project. In Ethiopia, National Project Coordinator (NPC) Rezene Fessehaie, along with Dr Taye Tessema, as Assistant National Project Coordinator (ANPC), and Dr Solomon Assefa, as National Project Director (NPD), all worked especially hard to raise the profile of IAS, eliciting the hands-on personal involvement of community members in IAS management actions, while extending generous hospitality to visiting project personnel.

In Ghana, 'Digi' Kweku Johnson (NPC) and Dr Felix Akbapey (ANPC), along with Dr Emmanuel Owusu-Bennoah (NPD, initially) and Dr Abdulia Salifu (NPD), were all very positive always about overcoming IAS management-related obstacles. 'Digi' was the consummate entertainer, ensuring that our field trips were never without laughs. In Uganda, Dr Gadi Gumisiriza (NPC), the late Mr Richard Bayo (ANPC), Peter Beine (ANPC) and Dr Denis Kyetere (NPD) were methodical and thorough in all their project work, producing any number of detailed reports. In Zambia, Brian Nkandu (NPC), Rodwell Chandipo (ANPC) and a succession of Project Directors, including Edward Zulu, Victoria Mupwaya and Paul Banda, were instrumental in raising an additional US$ 450,000 for IAS management in Zambia. Brian and his team were well organised and participatory, ensuring buy-ins for IAS management from across a range of sectors.

The meetings of the International Steering Committee were all chaired by Dr Kadera Chagema of the Kenya Plant Health Inspectorate (KEPHIS) – a wise man whose singular take on the challenges facing IAS management in Africa was encapsulated, at one meeting, in his wry observation: "The biggest challenge is not invasive species, but ourselves; how do we manage ourselves to manage invasives?"

There are of course many other people who contributed to the success of the project. The administrative staff in the participating nations, the Pilot Site Coordinators (PSCs), the Protected Area managers, and the consultants who were involved all played their parts. The PSCs and their teams made light work, often under trying circumstances, of clearing invasive plants from the pilot sites. Michael Nangalelwa and Griffin Shanungu from Zambia, who produced a series of fine reports and publications for the project, should be singled out for special mention. Both managed large teams of workers bent on clearing Lantana camara from the Mosi-oa-Tunya National Park, often on steep and dangerous slopes, and Mimosa pigra from the Lochinvar National Park (LNP). The LNP workers camped out near the infestations, leaving their families for long periods – a huge sacrifice. In Ghana, the project benefited from the encyclopaedic knowledge of FORIG technician Samuel Kyei Yamoah, who could identify almost every plant species in the Afram Headwaters Forest Reserve.

None of these people could have been involved in the project without the financial support of the Global Environment Facility (GEF), which contributed US$ 725,000 for the project's planning and preparation phase and an additional US$ 5 million for the full implementation phase. The host-country governments made significant contributions, amounting to US$ 4,392,980 in cash and in kind, during the project's implementation phase. Zambia contributed a further US$ 450,000 over and above its initial co-funding commitment. The Executing Agencies, CABI and IUCN, weighed in with co-financing support of US$ 1 million, in cash and in kind, during implementation. All are to be thanked for their considerable backing.

No list of project credits and acknowledgements would be complete, finally, without mentioning the considerable time and effort put in by writer Gordon Boy and Arne Witt in compiling this book. A Nairobi-based Kenyan freelance writer and editor specialising in environment-, conservation- and wildlife-related topics, Gordon is the author of a great many published articles and features in magazines and journals, including several on invasive alien species. He has also written books and natural history guides, and has edited a number of scientific reports. On this book, he and Arne – we feel sure you will all agree – have done an excellent job.

Dennis Rangi, Executive Director for International Development, CABI

Cattle and kids in Parthenium and *Calotropis procera* infested pasture near Welinchiti in the Oromia Region of Ethiopia, west of the Awash National Park ©Arne Witt

INTRODUCTION

Invasive alien plant management – now an essential priority for Africa

JOHN Wyndham's celebrated post-apocalyptic novel *The Day of the Triffids*, first published in 1951, describes the devastation visited upon Planet Earth by the escape and spread of a race of aggressive colonising plants. The plants, known as triffids, are accidentally introduced into a new environment. Here, despite their worryingly aggressive tendencies, they are found to be useful for producing vegetable oils. So they are cultivated on a massive scale. Their cultivation, emulated in other parts of the world, is soon the basis of a global agro-industry. Being highly opportunistic, the triffids are able, when advantageous conditions arise (in the novel, a meteor shower that coincidentally blinds most of the watching human population is the activating trigger), to explode into abundance, spreading uncontrollably. The result is massive environmental, social and economic devastation. The book ends with humanity still in retreat, groping for a solution to the catastrophe overwhelming the planet.

This may be the stuff of science fiction (in Wyndham's novel, triffids not only walk about; they also possess a lethal, whip-like sting, which they use to kill people, so they can gorge themselves on human flesh). These story elements aside, *The Day of the Triffids* is remarkably prescient – although not, perhaps, in the way the author intended. At the time, the novel was meant to be read as an allegory on the perils, in the run-up to the Cold War, of global bio-warfare (the triffids, after all, are bio-engineered Soviet plants, accidentally dispersed when an aeroplane carrying their seeds is shot down over the West). The novel might just as well have been conceived as a cautionary tale on the threat posed by real-life invasive alien plants …

Take the case of present-day eastern Ethiopia. Here, as in many other parts of the world, vast swathes of farmland and grazing pasture have been taken over by the noxious annual weed *Parthenium hysterophorus*. Unlike Wyndham's triffids, this invader came, not from the Soviet Union, but from Central America. Its seeds too arrived initially by air – in the early 1980s, probably in contaminated famine relief supplies. Parthenium Weed cannot walk about, but then it has no need of locomotion. It can spread itself around in harvests and food consignments, on the wind or in the water, on the wheels or in the radiators and under-carriages of motor vehicles and machines … even in mud clinging to the hooves of passing animals or to soles of our own shoes. Its abundant tiny seeds take care of this. Each dispersed seed can remain viable in the soil for two years – or longer, in some cases. A single germinating seed can then grow, within one month, into a mature plant capable of producing another 25,000 seeds.

Unlike the triffids, Parthenium Weed has never served any useful purpose. It does not sting, as such, but then it has no need of a menacing sting, for it contains potent allergens that can cause severe ailments in grazing and browsing animals, while also inflicting on people discomforting conditions such as dermatitis, asthma, hay-fever, breathing difficulties and irritations of the eyes. Its leaves, ingested in mixed forage, taint the flesh and the milk of livestock animals, imparting an unpleasant taste. Being allelopathic as well, it releases toxic chemicals into the soil, which prevent plants of other species from germinating and growing. Parthenium Weed does not kill people, at least not instantly, and nor does it eat human flesh. Instead, by slow degrees, it torments and starves people. It takes over their land.

Burn Parthenium and it will regenerate quickly – more rapidly than grassland plants of other species. Its competitive advantage enhanced, it will re-appear in even greater profusion than before. Cutting down or digging out the hated weed will have a similar effect, while at the same time helping the invading plants to scatter their plentiful seeds.

In parts of eastern Ethiopia, Parthenium Weed's impact on crop yields, mainly of sorghum and finger millet, has been so severe that even its local name, translated, means 'No Crop'. In some un-weeded fields, sorghum yields have plummeted by as much as 90%. Parthenium, though, is a comparative newcomer to Africa. Spreading fast, the weed is now also invading Kenya and other East African countries, having already independently invaded much of southern Africa (where it is called Demoina Weed). There too, the weed probably arrived initially as a seed-contaminant in food imports. In India, where it is known as Congress Weed, its infestations have been responsible for declines of as much as 40% in crop yields, and for reductions of as much as 90% in the livestock carrying capacities of grasslands. In some of India's worst affected areas, farmlands and pastures have been abandoned. Some despairing farmers have committed suicide. Whole communities have been driven off the land.

The implications for biodiversity are staggering. Hundreds of species of native grasses and other plants have been displaced from large areas of their core habitats. Parthenium Weed has found its way too into wilderness areas, national parks and nature reserves around the world. In Australia, the weed has irrevocably altered the make-up and ecology of many native grassland and open-woodland ecosystems. In Africa, the noxious invader is gaining a foothold in the savannahs of more and more protected areas, where – if its relentless advance cannot be checked – the survival of some entire populations of wild herbivores may soon be at risk.

It may be too late to save some grassland specialists. A Parthenium invasion of the Wajaale Plains on the Ethiopia–Somaliland border has prompted growing fears among ornithologists that Archer's Lark, *Heteromirafra archeri* – a rare bird species known only from this one locality – might already have been driven over the edge into extinction.

Parthenium Weed, then, shares many of the frightening characteristics of John Wyndham's fictional triffids. It is not alone, however. In a global context, it is not even the most talked-about or widespread of destructive alien invaders. It is just one of literally hundreds of invasive alien plant species which, on having been liberated from the natural constraints (imposed by climate, or by soil composition; by natural competitors, or enemies such as insects and mites, or diseases) that in a native habitat would keep their growth in check, are today spreading rapidly and wreaking havoc in new environments they have colonised in other parts of the world.

In the process, invasive alien species – of animal pests, viruses and pathogens, as well as plants – have become one of the most serious threats to the ecological and economic well-being of every habitat and region on Earth. With the biodiversity and food security of entire continents at stake, the battle to keep such species at bay has, in some of the world's wealthier nations, assumed the proportions of an all-out war. This is a very costly war, however. And it is an ongoing war. It is a war that must be able to draw on strong, well-funded institutions armed with clear strategies endorsed and backed by governments and supported by firm legislation and enforcement. In the United States alone, for example, the annual cost just of containing the spread of invasive alien species now runs to more than US$ 135 billion.

The poorer nations of the world, by contrast, have been unable to mount, much less sustain, such campaigns. The result, in many of these countries, and in those of sub-Saharan Africa especially, is that invasive alien species are running riot – with dire consequences, not only for agriculture, livestock productivity and water security, but also for fisheries, wildlife conservation and human health. The spread of invasive alien plant species, in particular, is damaging livelihoods in rural areas, aggravating poverty and hampering economic development, while at the same time irreversibly compromising biological diversity.

Financial constraints may explain, in part, why so many governments within sub-Saharan Africa have in the past chosen simply to ignore the problem. Now, as some of these governments are beginning to take notice, other difficulties are becoming apparent – over where to start, for example, and how to identify priorities. Moreover, there is very often a reluctance to intervene in cases of so-called 'conflict species' (invasive species, that is, which despite all the damage and suffering they are causing are deemed to possess some useful attributes as well). All these obstacles have translated, in the continuing absence in most African countries of effective policy instruments, and with no management strategies in place for tackling invasive alien species, into a worrying lack of action on the ground.

That is why, in 2005, the Global Environment Facility (GEF) embarked, in four African countries (Ethiopia, Ghana, Uganda and Zambia), on a four-year project geared to finding ways of overcoming such obstacles. The GEF-funded project – *Removing Barriers to Invasive Plant Management in Africa* – was implemented by the United Nations Environment Programme (UNEP). It was executed by CAB International (CABI) in collaboration with four national executing agencies and with assistance from the International Union for the Conservation of Nature (IUCN).

The project's four main objectives were: to raise levels of awareness with regard to invasive alien species; to strengthen policy in the four African countries towards the management of invasive species; to build the necessary institutional management capacity, and to develop and implement effective, practical and sustainable long-term strategies for preventing the influx, and limiting the spread, of invasive alien species, particularly plants. Elements of the National Invasive Species Strategy and Action Plans that were devised over the course of the project included systems of preventive interception, risk analysis, early detection and rapid response, and mechanisms for cost-recovery, as well as programmes of containment and control.

Lessons gained from implementing these strategies and actions have since been applied to similar endeavours elsewhere in Africa, and to GEF-funded projects in the Caribbean and in South EastAsia as well. Another of the project's central aims was to bring response levels within sub-Saharan Africa into line with the mainstream initiatives of well-established global instruments for restricting the spread of invasive alien species – such as those advocated by the Convention on Biological Diversity.

This book is just one of many outcomes of the project. In the book, we describe how the four-year project was instrumental in developing ways of limiting the severe ecological, social and economic impacts in different parts of Africa of a number of particularly devastating alien plant invaders …

In Ethiopia, we address – in addition to the ravages of Parthenium Weed – the destructive impacts of the Mesquite shrub, *Prosopis juliflora*, from Central and South America. Introduced in the early 1980s in a bid, championed at the time by some multi-national development agencies, to curb desertification in over-grazed arid and semi-arid areas of eastern Africa, Mesquite was meant to provide people with shade, fuel wood and building materials too, and with a plentiful source of supplementary fodder for their livestock herds. Instead, it has formed impenetrable shrubby thickets, invading watercourses, lowering the water-table and thus indirectly starving plants of other species of moisture and nutrients, creating what are known as 'green deserts', largely devoid of life.

In Zambia, we address the scourge of *Lantana camara*, now considered to be the most damaging of all widespread terrestrial invasive plants, being present in no fewer than 60 countries (including all the nations of sub-Saharan Africa). Native to Central and South America, Lantana was widely introduced during the early decades of the 20th Century as an ornamental shrub and hedge plant. Since then, having taken over vast expanses of farmland and grazing pasture, it has also invaded national parks and wilderness areas, overwhelming and replacing native plant communities. Elsewhere in Zambia, we address the destructive impacts of the Giant Sensitive Plant, *Mimosa pigra*, a prickly shrub from the tropical Americas that is rapidly invading floodplains and wetlands in many other parts of Africa as well.

In Ghana, we address the impacts of the Paper Mulberry, *Broussonetia papyrifera*, a deciduous tree introduced from the Far East in 1969 in a misguided government development scheme to establish a domestic pulp and paper industry. Although the scheme was subsequently aborted, the introduced trees have spread rapidly through forest reserves and outward into farmlands and livestock pastures – with disastrous consequences for biodiversity and rural livelihoods alike.

In Uganda, we address the menacing spread, in the Budongo Forest Reserve, a globally important biodiversity hotspot, of the Spectacular Cassia, *Senna spectabilis*, a fast-growing deciduous tree of tropical American origin that was brought to Africa by gardeners who admired its showy yellow flowers. The trees, planted by foresters as boundary markers around protected forests (including Budongo), went on instead to invade the reserves. Elsewhere in Uganda, we address the devastating impacts on pastoralist economies and savannah pasture ecosystems of invading tussocks of the unpalatable grass False Citronella, *Cymbopogon nardus*.

The Water Hyacinth, *Eichhornia crassipes*, universally regarded as the world's worst aquatic weed, having become a scourge in more than 50 countries, is another of the invasive alien plant species whose impacts we address in this book. In all four African countries participating in the UNEP/GEF project, this infamous invader – originally from South America – is having a catastrophic impact on the biodiversity of lakes and wetlands, as well as on fisheries and on the lives and livelihoods of the many millions of people in these and other countries in Africa who are dependent on the continent's freshwater ecosystems.

These are just some of the invasive alien plant species whose impacts, singled out for particular attention by the *Removing Barriers to Invasive Plant Management in Africa* project, we shall be addressing in the course of this book. There are of course many, many others. In the first part of the book, devoted to *Confronting the Problem*, we define invasive alien species and we examine their characteristics. We assess their dispersal pathways and explore the many different threats they pose – first from a global perspective and then within an African context. We consider various global, regional and national responses to the problem, and we outline key measures now in place around the world to combat the spread of invasive alien plant species.

In Part II of the book, under *The Challenges for Africa*, we identify barriers and stumbling-blocks that in the past have thwarted progress towards effective invasive alien plant management practices in Africa, and we explain how the project went about overcoming these impediments. We describe how the UNEP/GEF *Removing Barriers to Invasive Plant Management in Africa* project was implemented in the four participating countries. We take stock of the many positive outcomes that emerged, and we reflect on how the project has been instrumental in 'scaling up' awareness on the continent of the need to prioritise a range of integrated management strategies and actions for countering a growing menace which, today, no country in the world, and least of all in Africa, can afford to ignore.

PART I: CONFRONTING THE PROBLEM

CHAPTER ONE

Alien invaders and their impacts

Human mobility has fundamentally altered the make-up and the character of the biological world, as more and more species, relocated from their natural home environments, have – as aliens – been introduced, either intentionally or unintentionally, into the homelands of other species. This co-mingling of species, on the increase ever since the age of exploration, has accelerated dramatically in recent times, with the advent of mass transportation, travel and trade … and the onset of full-blown globalisation.

As providers of food and economic resources, useful introduced alien species fuelled humanity's sudden and explosive population growth in the Twentieth Century. Relentless habitat conversion and degradation, though, amid intensifying pressure to find space for more and more people and their useful alien plants and animals, has – against a backdrop of accelerating climate change – resulted in steep global declines in biological diversity.

Increasingly, both our planet's beleaguered biodiversity and the food and water security of our own species are threatened by the proliferation of other, less-than-helpful introduced alien species. These are the destructive aliens we call invasive alien species. The spread of alien plant invaders, in particular, is today ranked among the most serious of all threats besetting the ecological and economic well-being of our planet …

BIOLOGICAL diversity has been in decline ever since we humans started moving around the world. Rates of decline accelerated dramatically, however, during the 20th Century. Not only was this a period of explosive human population growth; it also ushered in the new age of mass mobility – and full-blown globalisation.

Amid sweeping technological advances came the development of today's familiar high-speed travel, trade and transportation networks. On these networks, it became possible – as never before – for people, in their millions, and their food crops and animals, farm produce and manufactured goods to move and be moved around the world with an ease and a rapidity that we now take for granted.

At the same time, as our fast-growing population dispersed, we needed more and more land on which to produce and to raise food. More land too had to be found for economic (cash) crops, for plantation-grown resources, and for the extraction of raw materials. All were needed in abundance to sustain our proliferating industries and expanding economies. Everywhere on Earth, ever larger swathes of forest and other naturally occurring habitats were sacrificed.

THE WORLD'S HUMAN POPULATION

The billion marks	reached in	time taken
1 billion	1800	Millennia
2 billion	1930	130 years
3 billion	1960	30 years
4 billion	1974	14 years
5 billion	1987	13 years
6 billion	1999	12 years
7 billion	2011	12 years
Projections		
8 billion	2023	12 years
9 billion	2034	11 years
10 billion	2045	11 years

Within just a few decades, as the 20th Century wore on, many of the planet's regionally distinctive natural communities – of native species of flora and fauna that had evolved together over millions of years in previously unmolested environments – were replaced with the same narrow range of introduced food plants and cash crops, introduced plantation trees and shrubs, introduced domestic livestock animals, and introduced decorative (ornamental) plants.

Of the estimated 480,000 alien species that, along with humanity, have infiltrated new environments around the world, the overwhelming majority (more than 90% in most regions) were introduced during the 20th Century. Many of these aliens we have introduced deliberately. Others we have transported unwittingly from place to place. A few of the alien forms have proved indispensable – at least to us. Collectively, they now account for no less than 96% of humanity's global food supply.

Some, alas, have turned out to be invasive alien species.

These are species – of non-native plants or animals, pathogens, or other organisms – that, on being introduced into environments to which they do not naturally belong, are able to become so well established as to transform and dominate the ecology of their adoptive homes. By suppressing or displacing resident species, or by subverting or disrupting the functional integrity and service delivery of colonised ecosystems, invasive alien species, once established, are able to spread rapidly, impoverishing biodiversity and undermining human welfare.

The aggressive newcomers go on to colonise neighbouring environments as well, out-competing and replacing native plant and animal communities. They may gobble up food supplies, or deplete precious water resources. Or they may overrun farmlands and take over pastures, muscling out other aliens that are useful or even indispensable to us, including our food crops and our livestock animals. Today, the alarming rate at which invasive alien species are proliferating poses a considerable and growing threat to the ecological and economic well-being of our planet.

The invasive aliens tend to be hardy generalists – versatile species, that is, which (unlike specialists) can adapt to a broad range of physical conditions, while being able to exploit a variety of foods and nutrients. On being deposited in a new environment, such aliens prosper in the absence of constraints – imposed by climate, predators, or rival species, or by parasites or disease – that in a home environment would keep their relative abundance in check. Invasive species are usually highly opportunistic too in being able to occupy vacant niches, or to capitalise on weaknesses resulting from conditions of ecological stress or disturbance induced by human activities.

Even so, it may take a while for an alien generalist to turn invader. First, such a species must become established. It must adapt fully. It must consolidate. In most cases it must find others of its kind. And it must reproduce. The settling-in process, known as the 'lag' phase of an invasion, may take a few years, or it may take decades. Lag phases of 50 years, or longer, are not uncommon. Put another way, the manifestation of any 'new' invasion may be the result of an alien species' introduction – or, more often, multiple introductions – dating back several decades. But then, once an invader has succeeded in building up a critical mass, it may suddenly explode into abundance. This is known as an irruption, and the ecological, economic and social consequences can be devastating …

The assault on biodiversity

Some of the most rapid and biologically cataclysmic alien species' invasions have occurred on islands, which historically, because of their long isolation in the oceans, have been particularly ill-prepared for the sudden arrival on their shores of aggressive colonising generalists from elsewhere in the world. The arrival in the 16th Century on the Indian Ocean islands of Mauritius and the Seychelles, for example, of humans and their ships sounded the death-knell for many species of endemic island birds, reptiles and amphibians.

The wave of extinctions that ensued (the Dodo's iconic demise included) was the work, not just of the ship crews themselves, but also of the many stowaway rats that disembarked along with the crews. The alien rodents – the Black (Ship) Rat, *Rattus rattus*, and the Brown Rat, *R. norvegicus* – proceeded to feast on the eggs and chicks of nesting birds, while depleting the birds' customary food sources. The subsequent introduction of domesticated Cats, *Felis catus* (to kill the soon-super-abundant rats), and of the Small Indian Mongoose, *Herpestes javanicus*, along with various other alien mammals, including free-ranging pigs and (on Mauritius) a species of Asian monkey as well, known as the Crab-eating Macaque, *Macaca fascicularis*, further hastened the mass-extinction process.

In more recent times, the ballast water carried from port to port on our cargo ships has proved a fecund pathway for spreading alien marine organisms around the world. Each year, more than 45,000 cargo ships collectively take on about 14 billion tonnes of ballast water. This is important for stabilising ships out on the open oceans. Ballast water pumped into a ship's holding tanks in one harbour is later disgorged in another harbour, often

Crab-eating Macaque (*Macaca fascicularis*) contributed to native species extinctions on Mauritius ©iStockimages

thousands of kilometres away. In the ballast water and in the ballast sediments, as well as on the hulls, of all cargo ships on the move across the oceans at any moment, marine organisms of no fewer than 7,000 species may be present.

Some of the travelling organisms have gone on to dominate new environments. Examples are the Comb Jellyfish, *Mnemiopsis leidyi*, discharged into the Black Sea with ballast water from North America's Atlantic coast, and – moving in the opposite direction – the Zebra Mussel, *Dreissena polymorpha*, from Eurasia, which currently infests the North American Great Lakes, having ousted many native shellfish species, disrupting the entire food web and causing fisheries to collapse. The Comb Jelly, for its part, has since spread to the Caspian Sea. Consuming fish eggs as well as plankton, it too has disrupted the ecological balance, harming local fisheries. Off the coastlines of southern Africa, some red tides (toxic algal blooms that can trigger mass-poisoning events higher up the food chain) have been attributed to dinoflagellate phytoplankton 'cysts' deposited in ballast water from visiting ships.

Stiffer regulations obliging ships to exchange ballast water out at sea rather than in harbours are now in place, amid calls too for rigidly enforced mandatory ballast-water-treatment regimens. The damage, though, may already have been done. Animal and plant life in marine environments around many of today's busier ports has long since been reduced to a hotchpotch of vigorous alien invaders – to the extent, in some regions, that native marine species are hard to come by.

Isolated freshwater lakes and wetland habitats, because of their delicate ecology, are also highly vulnerable. Lake Victoria, Africa's largest lake, occupying a surface area of roughly 69,000 km² (making it the world's second largest body of freshwater, after Lake Superior in the US), is a case in point. Here, the introduction in 1958 of the Nile Perch, *Lates nilotica*, an African fish that under auspicious conditions can grow to lengths of almost two metres, and which may weigh all of 125 kg, triggered what has been described as the biggest mass-extinction of vertebrates in recent times. In being responsible for the possible extinction, although this has never been proven scientifically and as such has been questioned by some, of no fewer than half of Lake Victoria's more than 400 native haplochromine cichlid fish species, this voracious predator has irrevocably altered the lake's ecology.

Although native to the River Nile, of which Lake Victoria is the primary source, and to other Nile-associated aquatic ecosystems further to the north, the Nile Perch had – until 1958 – been prevented from entering the lake by a succession of steep waterfalls. For scientific purposes, however, the Kajansi Research Station of the then Uganda Game and Fisheries' Department near Entebbe had kept some of the young perch in its holding ponds, not far from the lakeshore. Prolonged heavy rains in 1958 caused the nearby Kajansi River to burst its banks, flooding the station and sweeping these perch (along with other fish then also in the ponds, including alien Tilapia) into the lake. The Nile Perch's introduction, then, was an accident; but it was an accident, one might argue, that had been waiting to happen.

The Nile Perch has not been alone in disrupting Lake Victoria's native ecology. The arrival in the 1980s of the infamous Water Hyacinth, *Eichhornia crassipes*, has further altered the ecology. Native to South America, the Water Hyacinth – liberated from the diseases and other constraints it would encounter in its home environments – has been able to spread across the lake with impunity, covering vast areas of open water and clogging up bays and ports. Its thick, floating mats have prevented sunlight from penetrating through to the lake's littoral zones, while the spongy mats' decaying under-layers have depleted dissolved oxygen levels in the water. Whole communities of native underwater plant species may have been displaced as a result.

Between them, the Water Hyacinth and the Nile Perch have had a catastrophic effect on the lives and livelihoods of many of the Lake Victoria Basin's 35 million-plus

THE DESTRUCTIVE IMPACTS OF INVASIVE ALIEN PLANT SPECIES – AT A GLANCE

IMPACTS ON BIODIVERSITY

- As species' eliminators: By monopolising available water and nutrients, invasive alien plant species out-compete and replace native species of flora, impoverishing natural ecosystems, disrupting the animal food chain and subverting the delivery of essential ecosystem goods and services.

- As eco-disruptors: By dominating the ecology of the natural ecosystems they colonise, invasive plant species distort the evolutionary process, modifying the behaviour of pollinators, nutrient recyclers, seed dispersers and other ecosystem service-providers, destroying the niches of specialised native species of plants and animals, undermining mutualisms, and – in extreme instances – triggering the collapse of whole ecosystems.

IMPACTS ON HUMAN FOOD SECURITY, HEALTH AND LIVELIHOODS

- As water guzzlers: By reducing water flows and lowering water-tables, invasive alien plant species – many of which are exceptionally thirsty plants of large biomass and with deep-penetrating root systems – are a drain on the diminishing water reserves on which people depend for their survival and for the cultivation of their food-crops.

- As crop decimators: By reducing agricultural crop yields, infestations of invasive alien plant species are a cause of food scarcity and economic hardship in many regions. In subsistence economies, where people depend on what they are able to grow, famine, malnourishment and poverty are often the inevitable consequence.

- As destroyers of grazing pastures: By displacing nutritious indigenous grasses and herbs, infestations of invasive alien plant species – many of which are unpalatable or toxic – reduce forage productivity on pasture rangelands, resulting in reduced livestock carrying capacities. Malnourished or unhealthy livestock animals in turn have dire implications for pastoralists and for their health and their local economies.

- As disruptors of fisheries: By blocking light penetration and depleting levels of dissolved oxygen, invasive alien waterweeds destroy the phytoplankton communities that sustain fish food chains in healthy aquatic ecosystems. By clogging waterways and impeding boat traffic, or restricting shoreline access to water bodies, invasive plant infestations hamper fishing and other riparian activities and may trigger the collapse of fisheries.

- As despoilers of wildlife conservation areas: By driving out resident populations of wild fauna, invasive alien plant infestations undermine the integrity of natural habitats in Protected Areas. Unsightly thickets of invasive plants in National Parks and Reserves obstruct wildlife-viewing and cause such areas to lose their appeal as tourist attractions. Tourism earnings decline and tourism-based livelihoods suffer.

people. These are people who, for a ready source of protein, had long depended on a variety of different fish species taken from the lake. The commercial trawlers of a few export-driven fishing and fish-processing industries benefited handsomely after perch numbers irrupted in the early 1980s. For the poor majority, however, catches have plummeted, as species of smaller fish that had been much easier to catch have disappeared, and as accessible fishing grounds in shallow open water have been taken over by the hyacinth. This goes to show how biodiversity losses go hand in hand with diminished human food security, while demonstrating too how invading alien species can, at one fell swoop, be responsible for both ills.

The Water Hyacinth, now universally reviled as the world's worst aquatic weed, having become a scourge in more than 50 nations, owes its broad distribution to the beguiling appeal of its showy lavender-blue flowers. Generations of enchanted water gardeners from many countries, ever on the lookout for a decorative splash of colour, have carried away clumps of the noxious weed and have planted these in fishponds and garden wetlands around the world. Once established in such places, the prolific invader has not taken long to find its way, in pond debris and via overflows and spills, into rivers, dams and lakes.

Fateful early journeys

Some invasive alien species have been travelling around with us for hundreds of years and – like us – now frequent almost every habitat on Earth. Again, perhaps the best known are those pestilential rodents, the Black (Ship) Rat and the Brown Rat. Native to South-East Asia and China respectively, both are species that accompanied us and our bales of merchandise on the Silk Road and other trade routes in mediaeval times. Both went on to join us on later journeys, travelling the world as passengers on our voyages of discovery in ships. Both have thrived wherever we have taken them. And both, like us, have left a trail of devastation in their wake.

Like us, the alien rodents have triggered wave upon wave of extinctions among the native wildlife of many ecosystems around the world. They have not thanked us, either, for their free passage, proceeding at every opportunity to devour our crops and our food reserves. They have brought with them passengers of their own, which have visited terrible diseases on our populations. The bacterium *Yersinia pestis*, cause of the bubonic plague that in the 14th Century killed an estimated 75 million Europeans (then almost half of Europe's human population), was transmitted from the alien rats by fleas living on the rodents. The rats breed rapidly, so in most environments there is precious little we can do to control them. Indeed, in many regions their populations far outnumber our own. The destructive rodents, then, are with us to stay. And they are with us almost everywhere. Their destiny and ours are inextricably intertwined.

Unlike the rats, which were uninvited hangers-on, many of the destructive fellow aliens that accompanied us on our early voyages, and which go on plaguing us today, are species we transported *deliberately* from place to place. Several of these species are plants. Plants of one genus that would prove especially menacing in most of the new environments into which we introduced them are the *Opuntia* cacti – commonly known as Prickly Pears. Several *Opuntia* species, all native to the tropical Americas, were carried to Europe in 17th-Century Spanish ships returning from the New World. The fleshy fruits (or nopales) of one species, the Sweet Prickly Pear, *Opuntia ficus-indica*, in particular, were transported in huge quantities – as dietary supplements for the ship crews to consume en route, so as to prevent scurvy.

The spiny succulents are easily propagated, as each severed cladode of a cactus stem can take root and develop into a new plant. The transported Prickly Pears soon became naturalised in the Mediterranean, where they proved popular, not so much for their fruits (which, in the case of *O. ficus-indica*, were nevertheless assimilated into Mediterranean cuisine), as for planting as

NOT A PRETTY PICTURE

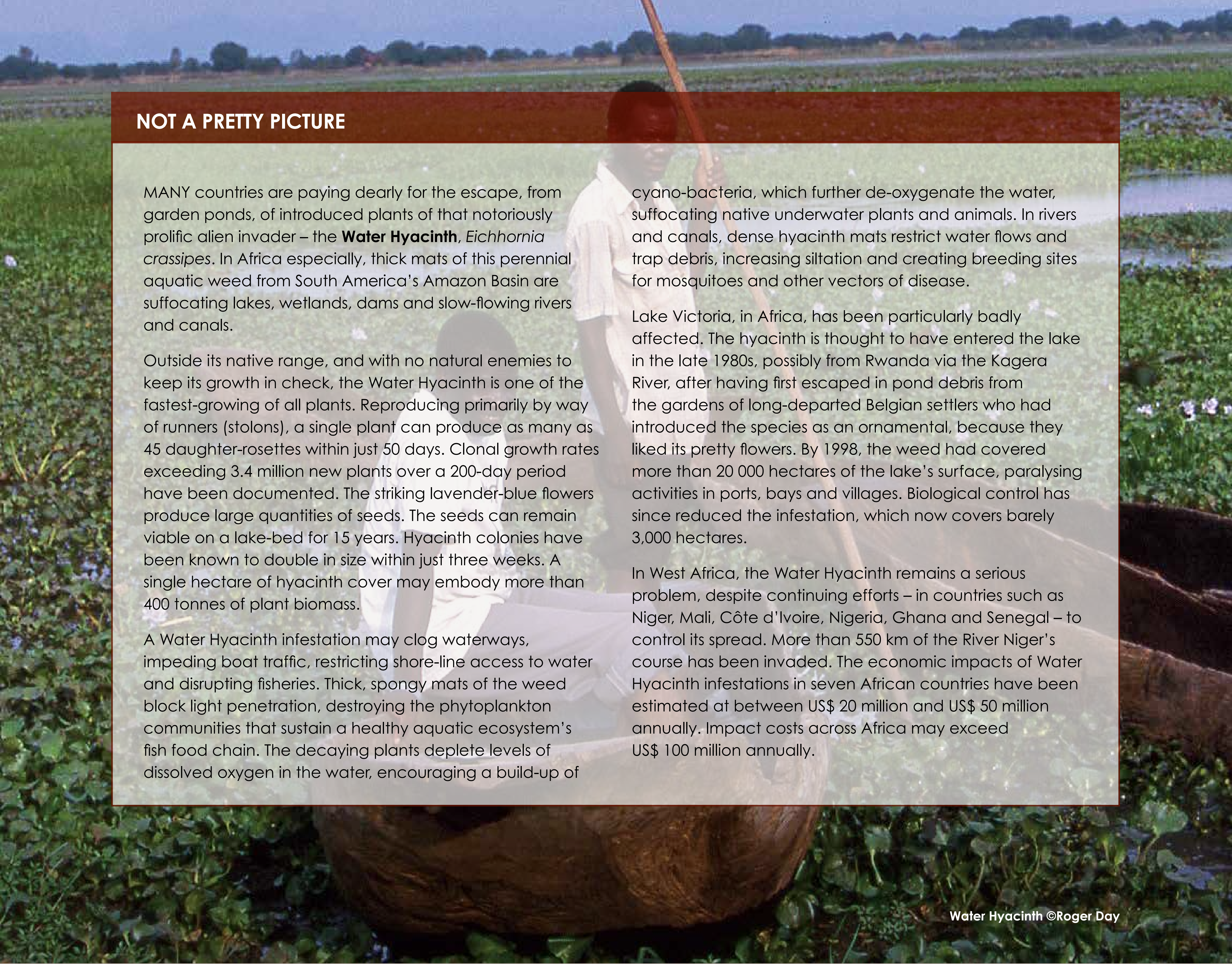
MANY countries are paying dearly for the escape, from garden ponds, of introduced plants of that notoriously prolific alien invader – the **Water Hyacinth**, *Eichhornia crassipes*. In Africa especially, thick mats of this perennial aquatic weed from South America's Amazon Basin are suffocating lakes, wetlands, dams and slow-flowing rivers and canals.

Outside its native range, and with no natural enemies to keep its growth in check, the Water Hyacinth is one of the fastest-growing of all plants. Reproducing primarily by way of runners (stolons), a single plant can produce as many as 45 daughter-rosettes within just 50 days. Clonal growth rates exceeding 3.4 million new plants over a 200-day period have been documented. The striking lavender-blue flowers produce large quantities of seeds. The seeds can remain viable on a lake-bed for 15 years. Hyacinth colonies have been known to double in size within just three weeks. A single hectare of hyacinth cover may embody more than 400 tonnes of plant biomass.

A Water Hyacinth infestation may clog waterways, impeding boat traffic, restricting shore-line access to water and disrupting fisheries. Thick, spongy mats of the weed block light penetration, destroying the phytoplankton communities that sustain a healthy aquatic ecosystem's fish food chain. The decaying plants deplete levels of dissolved oxygen in the water, encouraging a build-up of cyano-bacteria, which further de-oxygenate the water, suffocating native underwater plants and animals. In rivers and canals, dense hyacinth mats restrict water flows and trap debris, increasing siltation and creating breeding sites for mosquitoes and other vectors of disease.

Lake Victoria, in Africa, has been particularly badly affected. The hyacinth is thought to have entered the lake in the late 1980s, possibly from Rwanda via the Kagera River, after having first escaped in pond debris from the gardens of long-departed Belgian settlers who had introduced the species as an ornamental, because they liked its pretty flowers. By 1998, the weed had covered more than 20 000 hectares of the lake's surface, paralysing activities in ports, bays and villages. Biological control has since reduced the infestation, which now covers barely 3,000 hectares.

In West Africa, the Water Hyacinth remains a serious problem, despite continuing efforts – in countries such as Niger, Mali, Côte d'Ivoire, Nigeria, Ghana and Senegal – to control its spread. More than 550 km of the River Niger's course has been invaded. The economic impacts of Water Hyacinth infestations in seven African countries have been estimated at between US$ 20 million and US$ 50 million annually. Impact costs across Africa may exceed US$ 100 million annually.



Water Hyacinth ©Roger Day

ornamentals in garden rockeries and as live boundary partitions. From Europe, some species, notably the Erect Prickly Pear, *O. stricta*, and the Drooping Prickly Pear, *O. monacantha*, were later transported to other regions, reaching Australia in 1788 with colonists from Britain. There too, they were planted initially in rock-gardens and as living security barriers.

Over the next 140 years, introduced Erect Prickly Pears – liberated from their natural enemies, such as insects, mites, diseases, and other constraints that in a home environment would keep their growth in check – went on to occupy more than *25 million hectares* of the Australian outback, prompting the declaration (in the early 1920s) of a national disaster. By then, this fast-growing, drought-tolerant alien cactus species (now widely referred to as the 'Australian Pest Pear') had overwhelmed entire native plant communities, taking over productive pastures that might otherwise have continued to provide valuable grazing for those economically useful aliens, sheep and cattle.

Prickly Pears have since become a menace in many other regions. In Africa, some wildlife conservation areas – including South Africa's Kruger National Park – have become infested. Baboons, which pick, carry off and eat the ripe fruits, either spitting out the seeds or depositing the seeds in their dung, have helped to spread the plants. Efforts to eliminate infestations by the simple expedient of chopping down offending clumps of the cacti have served only to encourage the spread of the invaders.

Sweet Prickly Pear (*Opuntia ficus-indica*) is widely cultivated as a living fence and for its fruit but, despite these uses, it is extremely invasive in many parts of the world ©Arne Witt

Gradually then, over the centuries, as human mobility increased and as successive empires were able to extend their global reach and influence, bestriding continents and colonising distant lands, different plants and animals that had evolved well apart from one another, often in regions very widely separated geographically, were spread around the world – intentionally in some cases, in other cases as incidental stowaways or hangers-on, parasites, or contaminants.

Useful fellow aliens

Come the 20th Century and the new technological age of mass mobility and high-speed travel, trade and transportation links, this exchange process would accelerate dramatically. Introduced varieties, of a few domesticated food plants and animals in particular, enabled humanity to dominate the Earth. The result was an unprecedented surge in human population growth. A global population put at no more than 1 billion in 1800 climbed to 2 billion in 1930, and to 3 billion in 1960, before exploding to 4 billion in 1974, to 5 billion in 1987, and then to 6 billion in 1999 – going on, in 2011, to surpass the 7 billion mark.

Yet, as our numbers were exploding, the homogenising influence of globalisation saw us turn for sustenance to fewer and fewer domesticated food providers. Indeed, we came to rely, in the 20th Century, on fewer than 20 crop plants to provide more than 90% of our global vegetable intake. Of these, just three – wheat, maize, and rice – now account for more than half of humanity's global harvest. This compares with the roughly 6,000 food crops our forebears are known to have raised at one time or another throughout history.

The plants and animals we depend on today for the bulk of what we eat, wherever we may happen to live, are nearly all derived (through selective breeding) from alien species. Wheat, for example, now the most widely grown of our food grains, was first domesticated on the Mesopotamian floodplains of the Tigris and Euphrates (in what is now Iraq) 11,000 years ago. Rice was initially domesticated in the Far East, as were peas and various other pulses. Maize, first domesticated by the Mayas and the Aztecs of Central America from a species of wild grass known as *teosinte*, would not be grown elsewhere until well into the 16th Century, following the arrival in the New World of the Spanish conquistadors. The same is true of the potato, first domesticated by the Incas of the Peruvian Andes in South America – the continent which also gave the world cassava (manioc), the tomato, the papaya and the avocado.

Bananas, native to the jungles of India and South-East Asia, came to Africa with Indonesian and Arab seafarers, probably in the First Century, together with mangoes, native to the foothills of the Himalayas, and yams – from the islands of Micronesia in the West Pacific. Sugar cane, originally from Papua New Guinea, was domesticated in China and then in India, reaching Europe only in the Ninth Century, before going on (much later) to be transported around the world on Portuguese, Spanish and Dutch ships. Soya, now grown on a massive scale in the Americas, was first domesticated in China about 2,500 years ago, reaching North America only in 1767. China too gave the world apples (native originally to Kazakhstan) and citrus fruits.

Humanity's earliest cattle were domesticated independently in the Near East and in Africa from different wild taurine (ox) species and from that humped species, the Zebu, in the Indus Valley. The domestication process began roughly 9,000 years ago. Not until the 16th Century, again with the arrival there of the Spanish, would cattle be introduced to the Americas. Sheep and goats, both domesticated more than 10,000 years ago in parts of central Asia, were among humanity's earliest domestic livestock animals. Like cattle, sheep were unknown in the Americas until the 16th Century, and would not be shipped to Australia until near the end of the 18th Century. Chickens, now among the most widely distributed and important of all our food-providers, were initially domesticated 8,000 years ago in China and South-East Asia. Being relatively portable, they were easily transported, reaching the Americas more than 1,000 years ago in the boats of early Polynesian sailors.

In being able to introduce domesticated alien crops and livestock animals (suitably adapted through further selective breeding) into almost every habitat on Earth, *Homo sapiens* – alien invader supreme – was no longer constrained by having to live wholly within the bounds prescribed by Nature, and so could explode (irrupt) into abundance. More people meant having to create more space for the same few useful fellow aliens, which in turn meant yet more people … and so on. In the process, more and more of the planet's indigenous biodiversity has been sacrificed.

Destructive fellow aliens

Increasingly, what remains of our native biodiversity is concentrated in small 'island' refuges surrounded, not by open oceans, but by milling 'seas' of human settlement, cultivation and development – and, ominously too, by a rapidly encroaching tide of non-human invasive aliens. Historically, all island ecosystems have been particularly vulnerable to alien species' invasions and to the impacts of climate change. Species that have evolved on islands, many of them highly specialised, have no means of adapting to and nowhere they can go to escape such calamitous events. Extinction is often the inevitable result. Today, mainland species stranded on 'ecological islands' of humanity's making, from which they can no longer disperse, are threatened with the same fate.

For the biodiversity of marooned and increasingly fragmented 'island' habitats, it is invasive alien species of plants which carry

ECONOMIC LOSSES ATTRIBUTED TO INVASIVE ALIEN PLANT SPECIES			
Species	**Impacted economic activity and locality**	**Annual cost** (Estimated)	**Source**
Lantana, *Lantana camara*	▶ Crop production and grazing pasture for livestock in India ▶ Pasture production in Australia	US$ 924 million US$ 46.2 million	Singh et al. (1996) Swarbrick et al. (1998)
Leafy Spurge, *Euphorbia esula* Knapweed, *Centaurea* spp.	▶ Pasture production on rangelands in four US states (North Dakota, South Dakota, Wyoming, Montana)	US$ 134 million	Leistritz, Leitch, et.al. (1999); Hirsch, Leitch, et al. (1996)
Water Hyacinth, *Eichhornia crassipes*	▶ Fisheries and other activities (including hydro schemes), in seven African countries ▶ (including impacts of alien fish species, such as the Nile Perch)	US$ 20–50 million US$ 71.4 million	Joffe-Cooke (1997) Kasulo (2000)
Pines (*Pinus*), Hakea, Australian Wattles (*Acacia* spp.)	▶ Control costs (of restoring natural fynbos ecosystems) in the Cape Floral Region of South Africa	US$ 160 million	Higgins et al. (1997); Turpie & Heydenrych (2000)
Tamarisk ('Salt Cedar'), *Tamarix* spp.	▶ Water losses in the United States (25 states)	US$ 200 million	Zavaleta (2000)
Parthenium Weed, *P. hysterophorus*	▶ Stock reductions on beef ranches in central Queensland, Australia	US$ 5–17 million	Chippendale & Panetta (1994)
Purple Loosestrife, *Lythrum salicaria*	▶ Control costs in wilderness areas of the United States	US$ 45 million	ATTRA (1997)
Six species of noxious weeds	▶ Control costs in agro-ecosystems in Australia	US$ 105 million	Watkinson, Freckleton & Dowling (2000)

the greatest threat. In the United States, alien plants are colonising wilderness areas at the rate of roughly 700,000 hectares a year. One invader – *Lythrum salicaria* ('Purple Loosestrife'), introduced from Eurasia – is spreading at the rate of 115,000 hectares every year, despite the US$ 45 million that is being lavished annually on efforts to control its spread.

The fate of protected areas in Africa, where little is being done to arrest the spread of invasive alien plant species, may depend on how quickly actions can be taken to stem the relentless advance of such invaders. In the world-famous Serengeti–Masai Mara ecosystem of northern Tanzania and South West Kenya, for example, the noxious weed *Parthenium hysterophorus* has already gained a foothold. It may soon be joined by another menacing invader, *Chromolaena odorata*, now widespread on the fringes of this ecosystem. Both are unpalatable species that, once established, go on to replace nutritious native savannah grasses and herbs. So their proliferation – if this cannot be checked – poses a serious threat to the survival of some of the world's most iconic populations of wild grazing herbivores.

The ecological collapse of invaded conservation areas is now a very real threat in many parts of Africa. In Ghana and Uganda, as well as in Zambia and other parts of southern Africa, tourism is suffering already, as unsightly and obstructive thickets of invasive alien plants make wildlife-viewing difficult, causing some national parks and reserves to lose their appeal. The economic implications, for countries that depend to a large extent on revenues from tourism, are incalculable.

Yet it is other conservation threats that tend to dominate the headlines still – the poaching of glamorous large mammals, say, or the ravages of the bush-meat trade; the killing of roaming wild predators and crop-raiders; the depredations of trespassing loggers and charcoal makers, or the incursions into parks of people and their livestock herds. While all are important and valid concerns, it is alien plant invaders that should perhaps be uppermost on our minds; for it is the spread of invasive plants, ultimately, which – if they are allowed to go on proliferating – may prove the undoing of many of Africa's protected areas.

Sorghum field in Uganda invaded by *Parthenium hysterophorus* ©Arne Witt

Crop-yield and pasture losses

At the same time, the proliferation of alien plant invaders is undermining human food security in many regions. Across the developed world, invasive weeds alone are responsible for reducing overall crop yields by at least 10%. In some least developed countries – poor nations, many of them in Africa, which can least afford to bear such losses – weed infestations account for overall harvest declines of not less than 25%, although in some extreme instances (such as that of the *Parthenium hysterophorus* invasion afflicting parts of eastern Ethiopia), yield losses of more than 75% have been reported, with the result that in places the growing of sorghum, finger millet and other important subsistence crops has been discontinued altogether.

THE 'LETHAL' IMPACTS OF PARTHENIUM

THE annual herb *Parthenium hysterophorus*, known as **Parthenium Weed** and belonging to the Asteraceae sub-family Heliantheae, has in recent decades become one of the fastest spreading and most menacingly destructive of all alien plant invaders. Native to Mexico, Parthenium Weed has long been a scourge on the Indian sub-continent and in Australia, having in both regions been introduced accidentally in the 1950s as a seed-contaminant in imported produce. Since the 1980s, the weed has also been spreading rapidly in eastern Africa, after seeds were deposited inadvertently in Ethiopia, apparently amid contaminated famine-relief food supplies.

Few other invasive alien plant species have such wide-ranging and potentially lethal impacts on biodiversity and on human lives and livelihoods.

In India, where the species is known as **Congress Weed** (because the shape of its flowers is said to resemble that of the Congress Building in New Delhi), infestations of Parthenium Weed now cover millions of hectares in every state. The infestations are responsible for declines of as much as 40% in food-crop yields, and for reductions of as much as 90% in the livestock carrying capacities of some grassland areas. In Australia, a Parthenium infestation covering 17,000 hectares of central Queensland was found, over a ten-year period ending in 1993, to have reduced stock capacities on some beef ranches by 80%, representing average declines in annual earnings of between US$ 5 million and US$ 17 million. The condition and the average weights, meanwhile, of what cattle could be brought to market had also been declining, resulting in additional losses.

Parthenium hysterophorus **invasion in Ethiopia ©Geoffrey Howard**

In parts of eastern Ethiopia, Parthenium Weed's impact on crop yields, mainly of sorghum and finger millet, has been so severe that even its local name, translated, means 'No Crop'. In some un-weeded fields, Ethiopian sorghum yields have plummeted by more than 75%. Parthenium, though, is a relative newcomer to Africa. Spreading fast, the weed is now also invading Kenya and other East African countries, having earlier independently invaded much of southern Africa – where the species is called **Demoina Weed** (after Cyclone Demoina in 1983, which is believed to have carried seeds into South Africa from infestations in neighbouring Swaziland).

Parthenium Weed has also invaded wilderness areas, national parks and nature reserves around the world. In Australia, the weed has irrevocably altered the make-up and the ecology of many native grassland and open-woodland habitats. In Africa, Parthenium is gaining a foothold in more and more protected areas (including, recently, the Serengeti–Masai Mara ecosystem of northern Tanzania and South West Kenya and Uganda's Murchison Falls National Park), where – if its relentless advance cannot be checked – the survival of entire populations of wild herbivores may soon be at risk.

Usually no more than about half-a-metre tall (although taller under some conditions), Parthenium Weed looks altogether unremarkable, having deeply lobed pale grey-green leaves and bearing small compact heads of tiny five-lobed flowers, each one barely three millimetres across. Its deep tap-root helps it to monopolise available soil-moisture. This and the allelopathic effects of chemicals it exudes into the soil that are toxic to plants of other species, inhibiting their growth and preventing their seeds from germinating, enables Parthenium to suppress and to replace the native vegetation of colonised environments.

Parthenium Weed produces abundant seeds, which are freely dispersed by the elements, or by passing animals or people and their vehicles. Each seed can remain viable in the soil for two years – or longer, in some cases. A single germinating seed can grow, within one month, into a mature plant capable of producing 25,000 seeds. Seed-bank densities of 200,000 seeds per square-metre have been recorded on overrun, abandoned fields in India. Parthenium contains potent allergens that can cause severe, and eventually fatal, ailments (including gastro-intestinal, liver and kidney lesions) in grazing and browsing animals. Eaten in mixed fodder, Parthenium leaves taint the flesh and milk of livestock animals, imparting an unpleasant taste. Even the pollen of Parthenium Weed is allelopathic, reducing the chlorophyll content of plants of other species, while inflicting on people discomforting conditions such as dermatitis, eczema, asthma, hay-fever and irritations of the eyes.

Burn Parthenium and it will regenerate quickly – more rapidly than grassland plants of other species. Its competitive advantage enhanced, it will reappear in even greater profusion than before. Mowing down or digging out the hated weed will have a similar effect, while at the same time helping the invading plants to scatter their plentiful seeds.

In Ethiopia, Parthenium Weed has spread at an alarming rate, occupying hundreds of thousands of hectares of once-productive land. Across the rest of Africa, Parthenium's devastating impacts may soon eclipse even the destructive toll of long-established, familiar invaders such as *Lantana camara*.

A GLOBAL SCOURGE

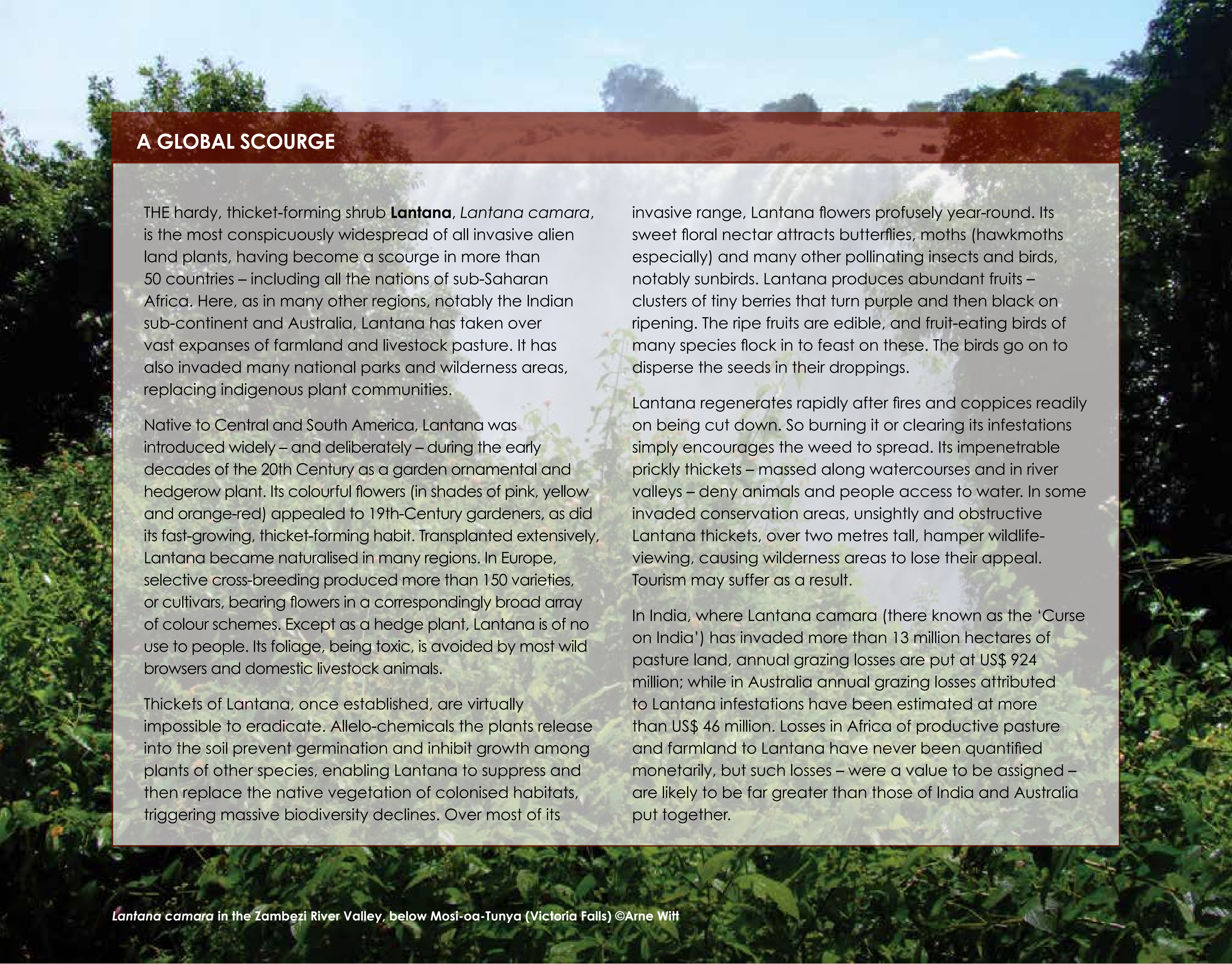
THE hardy, thicket-forming shrub **Lantana**, *Lantana camara*, is the most conspicuously widespread of all invasive alien land plants, having become a scourge in more than 50 countries – including all the nations of sub-Saharan Africa. Here, as in many other regions, notably the Indian sub-continent and Australia, Lantana has taken over vast expanses of farmland and livestock pasture. It has also invaded many national parks and wilderness areas, replacing indigenous plant communities.

Native to Central and South America, Lantana was introduced widely – and deliberately – during the early decades of the 20th Century as a garden ornamental and hedgerow plant. Its colourful flowers (in shades of pink, yellow and orange-red) appealed to 19th-Century gardeners, as did its fast-growing, thicket-forming habit. Transplanted extensively, Lantana became naturalised in many regions. In Europe, selective cross-breeding produced more than 150 varieties, or cultivars, bearing flowers in a correspondingly broad array of colour schemes. Except as a hedge plant, Lantana is of no use to people. Its foliage, being toxic, is avoided by most wild browsers and domestic livestock animals.

Thickets of Lantana, once established, are virtually impossible to eradicate. Allelo-chemicals the plants release into the soil prevent germination and inhibit growth among plants of other species, enabling Lantana to suppress and then replace the native vegetation of colonised habitats, triggering massive biodiversity declines. Over most of its invasive range, Lantana flowers profusely year-round. Its sweet floral nectar attracts butterflies, moths (hawkmoths especially) and many other pollinating insects and birds, notably sunbirds. Lantana produces abundant fruits – clusters of tiny berries that turn purple and then black on ripening. The ripe fruits are edible, and fruit-eating birds of many species flock in to feast on these. The birds go on to disperse the seeds in their droppings.

Lantana regenerates rapidly after fires and coppices readily on being cut down. So burning it or clearing its infestations simply encourages the weed to spread. Its impenetrable prickly thickets – massed along watercourses and in river valleys – deny animals and people access to water. In some invaded conservation areas, unsightly and obstructive Lantana thickets, over two metres tall, hamper wildlife-viewing, causing wilderness areas to lose their appeal. Tourism may suffer as a result.

In India, where Lantana camara (there known as the 'Curse on India') has invaded more than 13 million hectares of pasture land, annual grazing losses are put at US$ 924 million; while in Australia annual grazing losses attributed to Lantana infestations have been estimated at more than US$ 46 million. Losses in Africa of productive pasture and farmland to Lantana have never been quantified monetarily, but such losses – were a value to be assigned – are likely to be far greater than those of India and Australia put together.



Lantana camara **in the Zambezi River Valley, below Mosi-oa-Tunya (Victoria Falls) ©Arne Witt**

The impact of alien weed infestations on the productivity of pasture rangelands has been no less devastating. In many regions, forage losses to unpalatable invasive plants have reduced livestock carrying capacities three-fold, meaning (in some parts of southern Africa infested with *Chromolaena odorata*, for example) that livestock herds now need areas three times larger than before to access the same amounts of forage. In some *Parthenium*-infested pastures, on the Indian sub-continent as well as in Africa, forage losses amounting to 90% have been documented. In India, annual losses attributed directly to infestations of the invasive shrub *Lantana camara* from the tropical Americas, which has taken over more than 13 million hectares of once productive livestock pasture, were in 1996 estimated at US$ 924 million.

Even for wealthier nations, with well-developed Invasive Alien Species Strategy and Action Plans in place, the recurrent economic burden of pasture losses and lost crop production to invasive alien plant species is nothing short of staggering. In the United States, annual losses ascribed to alien weed invasions of croplands have been estimated at US$ 27.9 billion, while forage losses are put at close to US$ 1 billion a year. In Australia, combined annual forage and crop-yield losses to alien weeds were in 1995 estimated at US$ 4 billion. In South Africa, potential declines of as much as 70% in available pasture capacity have been reduced in some areas through sustained alien weed management interventions over the past 15 years.

In the absence of such management actions, countries elsewhere in sub-Saharan Africa, by contrast, have been able to do little to stem the swelling tide of alien plant invasions. On a continent where dependence on primary agriculture is paramount, and where for many people cattle are the life-blood (literally), not just of local economies, but of entire cultures and ways of life, the impacts of alien weed infestations are proving dire in the extreme. Pressures on dwindling natural ecosystems are mounting, as farmers and pastoralists – wracked by weed-related declines in crop yields and serviceable pasture – seek alternative land on which to make good shortfalls in their food production and grazing capacities.

Alien water-guzzlers

The combined effects of alien weed infestations and continuing deforestation and habitat loss are exacerbating another of the looming crises now besetting humanity – and that, of course, is the spectre of global water scarcity …

The need to grow more and more food to sustain our burgeoning populations has meant having to develop increasingly intensive farming methods. In some parts of the world, this has meant relying on ever more intensive irrigation systems. Demand for fresh water has increased dramatically as a result. Indeed, the global demand for fresh water is expected to rise by more than 50% between today and 2050. Across much of the developing world, home now to more than two-thirds of the world's human population, the demand for water is expected, by 2050, to outstrip available supply by more than half, placing very severe constraints on agriculture – and on the ability of populations in some nations to feed themselves.

Increasing water off-takes, coupled with the effects of deforestation and climate change, meanwhile, are reducing the water reserves of many countries, turning more and more historically perennial rivers into seasonal streams. Natural forests perform a critical role as live 'sponges' that generate precipitation and hold rainwater, which they go on to release gradually, ensuring under normal circumstances that rivers and streams can continue to flow, even over dry periods. The destruction or fragmentation of forest watersheds and of wetland habitats disrupts this hydrological equilibrium. Invasive alien plants, for their part, readily exploit such imbalances. Most alien tree species, moreover, are extremely thirsty plants.

Once established in watersheds, infestations of alien plants with extensive, deep-penetrating root systems and large biomasses may reduce substantially or even halt the water flows of river systems.

Chromolaena infested landscape in Ghana during the dry season ©Arne Witt

THE CURSE OF CHROMOLAENA

THE scrambling perennial shrub **Chromolaena**, *Chromolaena odorata*, known as **Triffid Weed**, has taken over pastures, farmlands and wilderness areas in many tropical and sub-tropical regions of the world, including vast swathes of habitat in sub-Saharan Africa. Native to Central and South America, this invader (also called **Siam Weed**) is thought to have arrived in Africa as early as 1937, probably as a seed-contaminant in produce off-loaded in Nigeria.

By 1995, Chromolaena had spread across much of West and Central Africa, from Guinea in the west to Angola in the south, and east into the Democratic Republic of Congo. It has since spread to Chad, Burkina Faso and the Gambia, and is now a menace too in Uganda and in parts of Tanzania and western Kenya. Another biotype, or form, of this species, traced back to seed-contaminated imports from the Caribbean, but which may also have been introduced deliberately as an ornamental, has spread widely across southern Africa. Chromolaena has become a threat too across South EastAsia.

Chromolaena grows quickly and produces a super-abundance of tiny light-weight seeds – more than one million per plant in a single flowering. The seeds are freely dispersed by the elements, as well as by animals and by people and their vehicles. Its flowers, borne in terminal clusters, are pale mauve or (in the case of the southern African invasive form) white. Its leaves, when crushed, smell of turpentine or paraffin (hence the scientific name *odorata* and hence also another of its nicknames – 'Paraffin Bush'). The shrub thrives on disturbed ground and readily invades farmlands and pastures, forming dense thickets, usually about three metres tall. As a scrambler in woodlands and in agro-forestry plantations, Chromolaena may climb to heights of up to ten metres.

As its density increases, Chromolaena affects the composition of grassland plant communities and disrupts forest successions, monopolising available ground water. In South Africa's KwaZulu-Natal Province, annual water losses attributed to Chromolaena have been estimated at 70 million m^3. The shrubs are highly flammable, even when young and green. This allows bush fires to penetrate deep into colonised forests and plantations. Chromolaena can, itself, regenerate rapidly after a fire. Being allelopathic too, the regenerating plants are able, in the aftermath of fires whose flames they have helped to fan, to inhibit recovery among plants of other species, and thus encroach further into burned plantations or forests. Chromolaena foliage contains compounds (flavonoids, terpenoids and alkaloids) which render the plant unpalatable to vertebrate herbivores.

In southern Africa, infestations of Chromolaena have reduced the livestock carrying capacities of some rangelands from approximately 6 ha. to more than 15 ha. per livestock unit. This means livestock herds need areas three times larger than before to access the same amounts of forage. High nitrate concentrations in the leaves of young plants browsed in mixed fodder have caused deaths among livestock and wild animals. Skin rashes and allergic reactions have been reported among people who have handled the plants.

Chromolaena has already invaded many conservation areas in Africa. Savannah, woodland and forest ecosystems in protected areas of Ghana and southern Africa have been especially hard hit. Tourism has suffered too, as unsightly and obstructive thickets of the weed hamper wildlife-viewing, causing some invaded parks and reserves to lose their appeal. In the 21st Century, Chromolaena has became established (together with Parthenium) within the world-famous Serengeti–Masai Mara ecosystem of northern Tanzania and South West Kenya. Spreading rapidly, it now poses a serious threat to the long-term viability of a wilderness area universally hailed as one the world's greatest remaining wildlife havens.

In South Africa, annual water losses attributed to invasive alien plants now amount to more than 3,000 million cubic metres – the equivalent of about 10% of all the river flows in the country. Potential further losses (of at least seven times this magnitude) may have been averted however, through the systematic, ongoing removal of various introduced Australian Wattles (*Acacia* spp.) and other water-guzzling invasive trees and shrubs, such as Prosopis, from water catchments and from riverbanks, under South Africa's innovative Working for Water (WfW) Programme (innovative, that is, in being run, not as a dedicated Invasive Alien Species Strategy and Action Plan, but as part of a broader national poverty-alleviation and job-creation initiative).

It is perhaps not surprising that some of the world's most effective management campaigns to root out alien plant infestations should be under way in heavily invaded countries which are also under particular pressure to conserve water resources that historically are naturally scarce. Fresh water supplies, though, in most other regions, are diminishing too, as wasteful use, pollution, salinity and moisture-sapping alien plants all take their toll on sinking water-tables depleted by unsustainably high off-takes.

The fuel-wood and timber trees we plant today in settled areas and on farmlands are almost entirely fast-growing alien species. Only the fastest-growing trees – those which produce the largest biomass in the shortest time possible – can keep pace with our spiralling supply needs. In most tropical and sub-tropical regions, it is the same few alien species we turn to. In sub-Saharan Africa, most are plantation species that were widely introduced during the colonial era, or which have been recommended by international development agencies and non-governmental organisations. The result is, that for miles on end, it is stands of Australian Eucalyptus 'Gums' and Grevillea (*G. robusta*) trees, along with Cypresses (mostly *Cupressus lusitanica*) of Central American origin, Pines (*Pinus* spp.) from the Americas and Europe, and Black Wattle (*Acacia mearnsii*), yet another import from Australia, which now constitute, not just the dominant tree-cover, but often the only tree-cover.

Around homesteads, meanwhile, species commonly grown for shade or to serve as windbreaks or as boundary markers include the Jacaranda, *J. mimosifolia*, from South America, the 'Indian Ash', *Acrocarpus fraxinifolius*, from Asia, and the Spectacular Cassia, *Senna spectabilis*, from the tropical Americas.

The fast-growing virtues of all these species come at an enormous price, however. All consume huge quantities of water. Some, like the Blue (Saligna) Gum, *Eucalyptus grandis*, an important fuel-wood and timber plantation tree, have been widely used as well (in years gone by, when water was more plentiful on the ground) for draining swamps and marshes in order to claim additional land for cultivation. Now, however, we need the water. So there have been efforts to remove these economically useful plantation trees from the vicinities of desiccated wetlands and seasonal floodplains. In South Africa, Eucalyptus trees alone reportedly consume as much as seven per cent of available ground water. By lowering the water-table, they impede crop growth and threaten native grassland plant communities. Their leaf falls inhibit undergrowth, as the micro-organisms that in Australia break down Eucalyptus leaf litter do not occur in Africa. Erosion often follows.

The Black Wattle, meanwhile, has earned itself a place among the world's 'Worst 100' invasive species listed by the International Union for the Conservation of Nature (IUCN). Plantations are widespread in Africa, where for more than 100 years the trees have been exploited commercially for tannins, extracted from their bark for use in the leather industry, and other bark extracts (used to make resins, thinners and adhesives), as well as for timber and fuel wood and as a source of woodchips for the pulp and paper industry. Yet the Black Wattle, despite all these useful attributes, has turned out to be a particularly menacing invader of watercourses and grasslands. In South Africa, its infestations

NOT SO 'SPECTACULAR', AFTER ALL

THE **Spectacular Cassia**, *Senna spectabilis*, a fast-growing deciduous tree from the tropical Americas, has been introduced into many countries around the world as a garden ornamental on account of its showy yellow flowers. It has also been used by foresters in some parts of Africa and South Asia as a boundary marker.

Rows of the trees, planted around forest edges, have been used to create a conspicuous 'buffer' separating forest reserves from adjacent farmlands. The Spectacular Cassia has, despite its deciduous nature, also been planted on some farms as a shade tree. Yet, as often happens with live hedges or with perimeter lines of fast-growing exotic shrubs or trees, the boundary delineators tend to advance into the native vegetation of the very habitats they are supposed to be helping to annexe.

In the Central Mountains Region of Sri Lanka, where these trees were planted as 'buffers' between highland tea plantations and forest reserves, invasive stands of *Senna spectabilis* have colonised large areas of disturbed forest at altitudes of up to 2,000 metres above sea level. Yet, despite the species' invasive characteristics, and despite its listing on the Global Compendium of Weeds, the Spectacular Cassia is still widely promoted in plant nurseries around the world as a decorative garden plant and as a 'useful' fuel-wood and shade tree.

Stands of *Senna spectabilis* now occupy more than 1,000 hectares of Uganda's Budongo Forest Reserve and environs, having out-competed and replaced whole communities of native forest plants. The invading trees, which may reach heights of 15 metres, but which are usually no more than half this height, typically have short, forked grey boles and spreading crowns of drooping branches. They grow well even in infertile or degraded soils. They do not fix nitrogen, even though they are legumes. Their extensive root systems are capable of soaking up moisture and of absorbing nutrients from deep-soil horizons. They produce abundant seeds in long cylindrical pods that are readily dispersed by the elements, on machines, or by animals or people. Their foliage is unpalatable.

are today one of the gravest threats to the Fynbos vegetation of the Cape Floral Region, one of the most bio-diverse plant communities on Earth.

Alien 'conflict species'

Like Eucalyptus and like many other introduced agro-forestry plantation trees, the Black Wattle is what is known as a 'conflict species'. On the one hand, such species are very useful and important economically, while on the other they damage human interests through compromising water security and reducing agricultural and livestock productivity. Optimising the trade-off between the positive and the negative aspects of introduced conflict species is today one of the most pressing of all land-use and resource-management challenges.

The same applies to a number of the other alien plant species introduced over the course of the 20th Century on the recommendation of agro-forestry organisations and multi-national development agencies. Inter-cropping with *Leucaena leucocephala* – a fast-growing, drought-tolerant, nitrogen-fixing leguminous tree from Central America – has been widely promoted in Africa, for example, as a soil-improver and as a fodder and fuel-wood resource. Dubbed the 'Miracle Tree', the species became the mainstay of many well-intentioned schemes to boost agricultural and livestock productivity on the continent. Leucaena, though, in most of the places where it has been introduced, has proved as well to be a prolific coloniser of forest margins, roadsides, riverbanks and cultivated land, forming thickets that can be difficult to eradicate, as the plants re-sprout vigorously on being cut down or trimmed back.

Both the foliage and the seed-pods of Leucaena contain the amino acid mimosine. In Africa, the rumen micro-organism that enables some Central American species of browsing animals to break down and digest mimosine is lacking, however, rendering these plants toxic to livestock. Animals that browse repeatedly on Leucaena pods and leaves become listless. Losing appetite, they shed weight and experience hair-loss. Higher nitrate concentrations in soils enriched by Leucaena, while undeniably helpful in some circumstances, have 'drowned out' some native plant communities that have evolved in adaptation to soils which are naturally nutrient-poor.

The negative impacts in Africa and elsewhere of Prosopis (or Mesquite), another widely introduced legume from the Americas, are only now becoming apparent (*see Accompanying Box, pp. 43-45*). Prosopis has in the past been widely championed as a panacea for stabilising and enriching soils and for halting encroaching desertification, while providing people in arid and semi-arid regions with shade, fuel wood and building materials, along with a plentiful source of fodder for their livestock herds. Instead of developing into useful small trees, however, the introduced Prosopis has in many areas formed impenetrable shrubby thickets, invading watercourses, lowering the water-table and starving plants of other species of moisture and nutrients. So, while Prosopis may, in one way, have helped to stitch up the soil and halt advancing deserts; in another, it has created 'green deserts' through depleting vital ground-water reserves in some of the world's most water-scarce environments.

Today, amid growing alarm over looming energy shortages, it is biofuel plants – such as the Oil Palm, *Elaeis guineensis*, and *Jatropha curcas* – that are being touted as new 'wonder' crops for the developing world. The prospect of massive investment inflows has made it difficult for the governments of some poorer nations to resist the temptation proffered by foreign backers of proposed large-scale biofuel plantation schemes. One proposal, turned down by Kenya's National Environment Management Authority in 2012, sought to replace 50,000 hectares of the Dakatcha Woodland near Malindi with a commercial Jatropha plantation. Other proposed schemes, in Kenya and elsewhere in Africa, remain under consideration, however.

Known in some parts of the world as Physic Nut, Jatropha is a very fast-growing, water-guzzling, drought-tolerant species from the tropical Americas belonging to the Spurge Family, Euphorbiaceae. Although widely grown in Asia for the vegetable oil its seed produce, its efficacy as a fuel source remains largely unproven. Widespread already in Africa, its introduction is prohibited by some countries (such as Australia), on account of its invasive, weedy tendencies.

The zeal with which some alien biofuel crops are being promoted is reminiscent of how, not so long ago, other aliens (such as Prosopis) that in some cases went on to become troublesome invaders were championed for *their* perceived benefits – at a time when nitrogen-fixing soil-improvers and sand-stabilisers for halting encroaching deserts were all the rage on the international development agenda. There is a danger, then, that in the headlong rush to solve one problem (looming fuel shortages, in this instance) humanity may succeed only in exacerbating a whole raft of other problems – by incurring unsustainable additional biodiversity declines and water losses, while reducing further the extent of farmland and pasture available for food production.

Alien invaders and climate change

Another factor that today, increasingly, is transforming the make-up and the character of human-altered biological environments around the world is of course accelerating climate change, driven by rising concentrations in the atmosphere of carbon dioxide and other greenhouse gases …

Climate change is not a new phenomenon. Countless times over the aeons, as the Earth's climate has changed, extinctions have occurred. The composition of natural ecosystems has been altered. Many species, though, have been able to survive – some through a process of gradual adaptation, others through being able to find refuge in more compatible adjoining habitats. Today, few such alternative ranges exist. Most have been engulfed by human activity and sprawl. This time round then, the ravages of climate change are likely to be especially severe. Whole communities of species, marooned in isolated and fragmented 'island' habitats and surrounded already by an encroaching sea of aggressive alien invaders, may succumb.

Over the course of the 21st Century, half of all the species now represented on the planet may become extinct, scientists believe. The anticipated tsunami of extinctions would be the sixth such event in the Earth's history – and the first since the asteroid strike 65 million years ago that accounted for the dinosaurs. The difference this time is that the probable cause will not be some momentous natural calamity. Instead, the predicted 'Sixth Extinction' is likely to be the result of humanity's own relentlessly destructive actions.

Most invading alien plants, for their part, are benefiting from the effects of climate change, particularly in areas where environmental degradation or disturbance is also a factor. As hardy generalists, the alien invaders typically prosper under a far broader range of environmental conditions than their more specialised native counterparts. So conditions of ecological stress and hydrological imbalance induced by melting ice-caps and extreme weather events such as protracted droughts and flash floods (and compounded in some regions by more frequent cyclones and bush fires too) all help alien invaders to become established in disturbed environments – and to spread at the expense of native plants.

Fast-growing alien plant invaders are benefiting too from the increasing levels of greenhouse gases in the atmosphere. In particular, the higher concentration of carbon dioxide, from which all plants photosynthesise, boosts plant growth rates, while also reducing (in what is known as lower stomatal conductance) their water loss through transpiration, thereby enhancing water-efficiency. Whereas in theory all plants should respond equally to

Wattled crane habitat is rapidly being lost due to the proliferation of *Mimosa pigra* ©iStockimages

THE RAVAGES OF A 'SLEEPING GIANT'

SEASONAL wetlands and floodplains around the world have in recent decades become increasingly susceptible to invasion by the **Giant Sensitive Plant**, *Mimosa pigra* – a prickly, scrambling shrub from Central and South America. In many regions where it has been introduced, *Mimosa pigra* has turned invasive suddenly, after long periods of naturalisation (in some cases extending over more than 60 years). The species' sudden awakening, in so many of the areas where its infestations are now an intractable menace, may have been triggered, in part at least, by the effects of a warming climate on the altered hydrology of disturbed wetland ecosystems.

The first reported large-scale Mimosa invasions occurred in the late 1960s in Australia's Northern Territory. There, the species has continued to spread rapidly and now infests more than 80,000 hectares of coastal floodplain, while also threatening to overrun the Kakadu National Park, a World Heritage Site. The plants have also taken over floodplain areas on Papua New Guinea and other South Pacific islands.

In sub-Saharan Africa, there have been numerous infestations since the early 1980s. *Mimosa pigra* has invaded seasonal floodplains and wetlands in Zambia, Mozambique, Malawi, Ethiopia, Ghana and Uganda, to name just some of the worst affected nations. On the Kafue Flats in Zambia, mono-specific stands of Mimosa now cover more than 3,000 hectares of farmland, pasture and wilderness, including much of the protected floodplain habitat in the Lochinvar National Park, home of the endemic Kafue Lechwe, *Kobus leche kafuensis*, a vulnerable antelope subspecies, and an important refuge too for the endangered Wattled Crane, *Grus carunculatus*. A similar invasion is under way in the Gorongosa National Park in central Mozambique.

In Thailand, Vietnam and Cambodia, infestations of *Mimosa pigra* have, since the early 1990s, choked irrigation systems, disrupted fisheries and invaded rice paddies, decimating crop yields and damaging farming livelihoods. Mimosa's continuing spread is also threatening Vietnam's Tram Chim National Park – today one of only a few remaining protected areas of seasonally inundated native grassland habitat in the Mekong Delta.

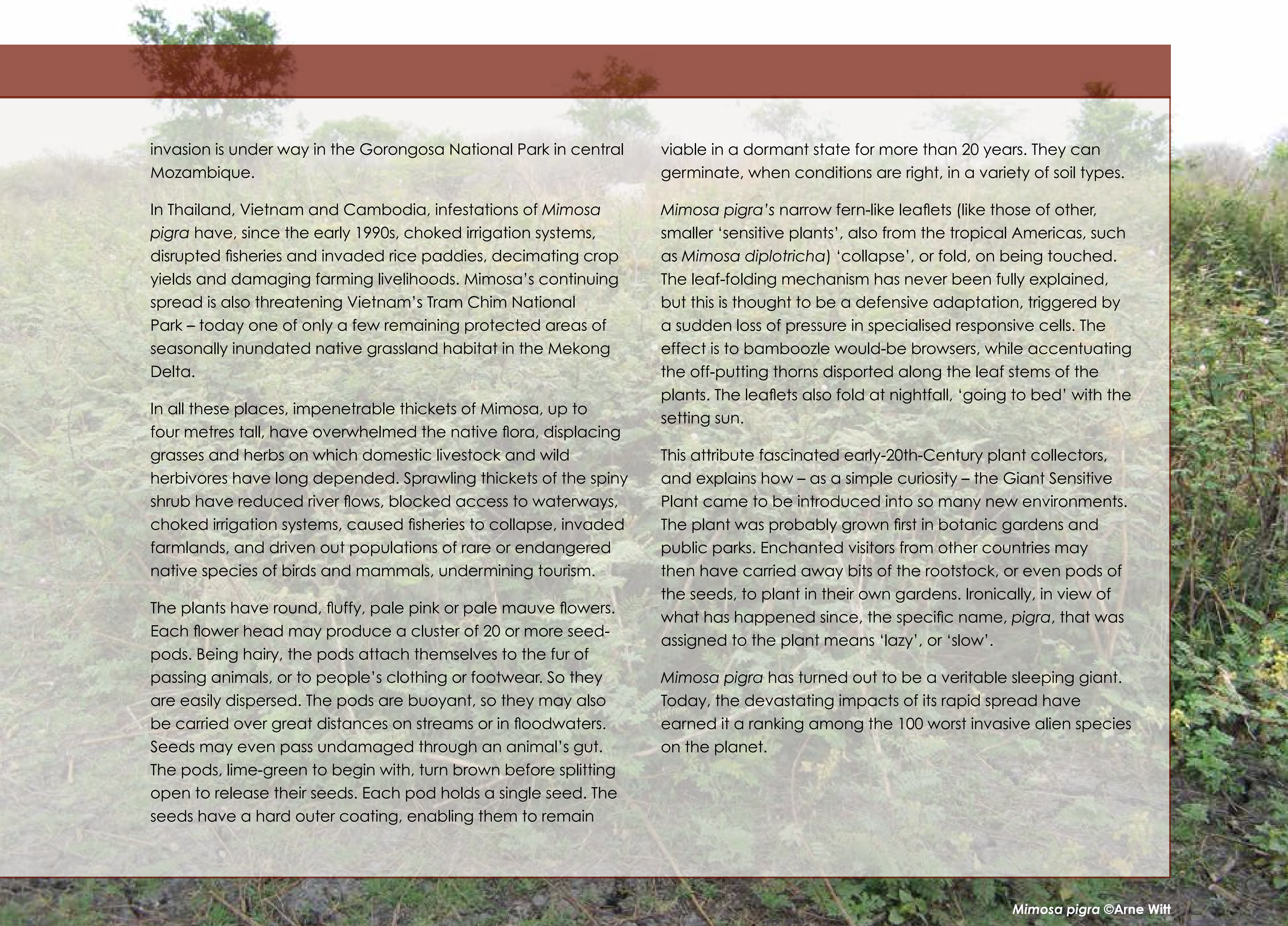
In all these places, impenetrable thickets of Mimosa, up to four metres tall, have overwhelmed the native flora, displacing grasses and herbs on which domestic livestock and wild herbivores have long depended. Sprawling thickets of the spiny shrub have reduced river flows, blocked access to waterways, choked irrigation systems, caused fisheries to collapse, invaded farmlands, and driven out populations of rare or endangered native species of birds and mammals, undermining tourism.

The plants have round, fluffy, pale pink or pale mauve flowers. Each flower head may produce a cluster of 20 or more seed-pods. Being hairy, the pods attach themselves to the fur of passing animals, or to people's clothing or footwear. So they are easily dispersed. The pods are buoyant, so they may also be carried over great distances on streams or in floodwaters. Seeds may even pass undamaged through an animal's gut. The pods, lime-green to begin with, turn brown before splitting open to release their seeds. Each pod holds a single seed. The seeds have a hard outer coating, enabling them to remain viable in a dormant state for more than 20 years. They can germinate, when conditions are right, in a variety of soil types.

Mimosa pigra's narrow fern-like leaflets (like those of other, smaller 'sensitive plants', also from the tropical Americas, such as *Mimosa diplotricha*) 'collapse', or fold, on being touched. The leaf-folding mechanism has never been fully explained, but this is thought to be a defensive adaptation, triggered by a sudden loss of pressure in specialised responsive cells. The effect is to bamboozle would-be browsers, while accentuating the off-putting thorns disported along the leaf stems of the plants. The leaflets also fold at nightfall, 'going to bed' with the setting sun.

This attribute fascinated early-20th-Century plant collectors, and explains how – as a simple curiosity – the Giant Sensitive Plant came to be introduced into so many new environments. The plant was probably grown first in botanic gardens and public parks. Enchanted visitors from other countries may then have carried away bits of the rootstock, or even pods of the seeds, to plant in their own gardens. Ironically, in view of what has happened since, the specific name, *pigra*, that was assigned to the plant means 'lazy', or 'slow'.

Mimosa pigra has turned out to be a veritable sleeping giant. Today, the devastating impacts of its rapid spread have earned it a ranking among the 100 worst invasive alien species on the planet.



***Mimosa pigra* ©Arne Witt**

this stimulus, in practice it is primarily the aggressive aliens that profit. Quick to take advantage, they grow more vigorously and spread more rapidly – to the detriment of slower-growing plants of other species.

Warming temperatures in some regions, meanwhile, are creating ripe conditions under which some alien plant species previously thought of as benign may suddenly turn invasive. Such plants are known as 'sleeper' weeds. A dramatic example is the Giant Sensitive Plant, *Mimosa pigra*, a widely introduced prickly shrub from the tropical Americas whose sudden awakening in so many of the regions where it is now an intractable menace (in some cases after having been naturalised for periods of 70 years or more) may have been triggered, in part at least, by the effects of accelerating climate change on the altered hydrology of wetland ecosystems.

Diminished food security

At the same time, as available space diminishes and as we humans need to keep on stepping up our food production, we have come to depend on fewer and fewer high-yielding hybrid *strains* of our few domesticated plants and animals, so further eroding the diversity of our food-base. Having to raise more and more produce in less and less space has meant abandoning the less productive varieties of most of our current food staples. The natural ancestral forms of some important food providers have been lost in the process. Indeed, for most of our staple crops, more than half of the varieties available to us before the 20th Century may now be extinct.

This steep decline in genetic diversity among the domesticated plants and animals we depend on for our sustenance has placed the future food security of our species on a precarious footing. For want of some of the more robust genetic traits embodied in lost or imperilled forms, our few remaining food providers have become particularly vulnerable to the effects of ongoing climate change – and to the ravages of diseases transmitted by invading alien organisms.

As much as 90% of all wheat grown today, for instance, has no resistance to the Stem Rust fungus, *Puccinia graminis*, a rapidly-mutating invader whose most recent incarnation, called Ug99 (because the strain was first detected in Uganda in 1999), has been spreading fast in recent years. Spores of the fungus are easily transported in contaminated produce or even on the shoes or in the baggage of unsuspecting airline passengers. By 2009, Ug99 had reached the Middle East and was threatening the breadbaskets of Asia.

A much earlier strain of *Puccinia graminis*, inadvertently shipped from Europe to North America with introduced wheat as early as the 17th Century, was – by early in the 20th Century – threatening to create serious food shortages in the US. There, it took a massive effort first to control and then to eliminate the fungus. This entailed the systematic eradication of another alien invader, the Common Barberry, *Berberis vulgaris*, a plant which had been introduced (deliberately) at roughly the same time. Not until the 19th Century was the barberry identified as another of the host plants of the *Puccinia* fungus.

The US Stem Rust eradication campaign of the early 20th Century is today justly hailed as one of the most successful undertakings of its kind in history. There can be no resting on laurels, however. Strains of invasive alien fungi remain an ever-present threat, particularly where crops are grown in large-scale monocultures. And besides, the costs and the logistics of mounting and of sustaining such eradication campaigns are today well beyond the capacities of most nations.

There are few more harrowing examples in history of an alien invader's impact on a society overly-dependent on just one type of alien food plant than that of the Late Potato Blight, *Phytophthora infestans*, in 19th-Century Ireland. Between 1845 and 1852, the blight – an oomycete (or water mould), thought to have been introduced in contaminated guano shipments from Peru – destroyed successive Irish potato crops, causing the Great Famine in which more than one million people died of starvation.

THE PAPER MULBERRY TRAIL

SOME alien plant infestations are the legacy of misguided government development schemes. In Ghana, for example, in the late 1960s, the then-Government wanted to establish a domestic paper and pulp industry. So the Forestry Research Institute of Ghana imported some **Paper Mulberry**, *Broussonetia papyrifera*, seedlings from the Far East. There, the bark of the trees had been used for centuries to produce paper. The seedlings arrived in 1969 and were duly planted out in two trial plots, so their potential as the basis for a new Ghanaian industry could be evaluated. The trial plots were located beside two of the country's most important forest reserves: the Pra-Anum Reserve and the Afram Headwaters Forest Reserve.

This would prove a recipe for disaster. The Paper Mulberry is an exceptionally fast-growing deciduous tree. Mature trees may reach heights of up to 12 metres. Broussonetia is dioecious, producing male and female flowers on separate trees. Its roots, though shallow, are extensive, propagating by vegetative means and radiating outward in thick, ever-expanding fibrous mats that re-sprout relentlessly while soaking up huge amounts of water. Cutting down the trees encourages the root systems to coppice, helping the trees to spread. Male flowers produce a super-abundance of pollen. Female trees produce fruit twice a year. The fruits, ruby-red when ripe and plentiful in season, are sweet-tasting, juicy and edible. Fruiting trees attract numerous birds, along with bats and other mammals, which go on to disperse the seeds – over considerable distances.

In Ghana, both male and female trees were planted. (In some South Pacific island states, by contrast, only male trees were introduced, albeit not so much for paper-making as for producing 'tapa' bark-cloth.) Ghana's trees flourished in their new environment. They soon made themselves at home too on the edges of the adjacent forest reserves. A succession of forest fires in West Africa during the drought-prone 1980s was the trigger for the spread of the trees. The fires opened up the forest canopies, allowing deposited mulberry seeds to germinate. The Paper Mulberry has since spread deep into the forests. The rampaging plants have proliferated along roadsides and have invaded other Ghanaian forests, some more than 100 km away, taking over farmlands and pastures as well.

The Ghanaian Government abandoned its paper and pulp project in the early 1970s. The aborted project will never be forgotten, though, for having irreparably undermined the ecology of two of Ghana's most important biodiversity hotspots. Now disparagingly referred to in Ghana as 'York' (the name of the official responsible for overseeing the trial plots), the Paper Mulberry has – through a combination of vigorous growth and insatiable thirst – suffocated the under-storey forest vegetation, starving and replacing native forest plants.

The Paper Mulberry thrives under a broad range of climatic conditions in many habitat types, ranging from humid tropical and sub-tropical to temperate environments. It has been introduced into many countries, including the United States, not for making paper or bark-cloth, but simply as a fast-growing ornamental shade tree. In all these countries, Broussonetia papyrifera has become a menacing invader. In the US, it has colonised park lands, forest edges and plantation verges from Illinois to Massachusetts, spreading south into Florida and west into Texas. It has become a troublesome invader of the Pampas grasslands of Argentina. It is ranked among the worst invading plants in Pakistan, where it is notorious above all for the pollen allergies it causes in Islamabad while it is flowering (in February–April).

Another African country in which the Paper Mulberry has become a serious ecological threat is Uganda. The Budongo Forest Reserve in the west of the country near Lake Albert, famous not only for preserving the largest intact expanse of forest on the eastern rim of the Albertine (Western) Rift Valley, but also as a refuge for the easternmost wild population in Africa of the imperilled Common Chimpanzee *Pan troglodytes*, is the site of a particularly worrying Paper Mulberry invasion.

***Broussonetia papyrifera*, commonly known as Paper Mulberry ©Arne Witt**

The equivalent death toll today, were such a calamity to befall (say) the United States, would be of the order of 50 million. Such are the perils of relying on high-yielding strains of just a few highly in-bred food plants.

Around the world, meanwhile, plants of many species – some of which may have been of enormous potential benefit to humankind (in providing medicines, as well as food), nobody can say how many – have been lost. The science of ethno-botany is a belated rearguard action aimed at preserving, before it is altogether too late, what is left of the disappearing stores of knowledge accumulated by marginalised minority cultures with no written record of the uses they have found for native plant species of theirs that have not already been extirpated.

The loss of medicinal plants, in particular, has potentially serious implications for human health and health care. The active ingredients in no less than one-third of all the Western pharmaceuticals in common use today are derived from plants and plant extracts. Aspirin, for example, one of the world's most important and widely taken medicines, is derived from salicylic acid, a compound discovered in Willow (Salix) bark and in the Meadowsweet, *Spiraea ulmaria*. Yet only a small fraction of the Earth's plant species (fewer than 10%, according to most estimates) have so far been examined for natural compounds that may be of medicinal value. The outlook for poor countries, where rural communities depend for more than 75% of their primary health-care needs on traditional herbal remedies, is considerably bleaker, given the rate at which medicinal plant species are disappearing.

Agronomists, for their part, have succeeded over recent decades in 'resurrecting' and preserving unheralded surviving wild forms of some of our more common food plants. The cross-breeding of these forgotten or previously ignored wild forms with cultivated varieties has helped to restore some of the genetic diversity and vigour of a number of our food staples. The enhanced diversity has in turn increased the capacity of some individual crops to resist pests and diseases and to withstand the vagaries of climate change. The re-discovery in the wild of such 'lost' forms is a testament to the inestimable value of natural biodiversity in preserving wild taxa that may yet prove indispensable to humanity's own continued survival.

The challenges before us

The survival of our species will depend, ultimately, on whether we can safeguard enough of what remains of our planet's precious biodiversity (and the all-important ecosystem goods and services this biodiversity delivers), while at the same time also conserving enough water and producing sufficient food, energy and other essential resources to sustain our burgeoning numbers. With more than 7 billion people on the planet already, and with that number expected to exceed 9 billion by 2040, this is of course a formidable challenge – particularly during an age of global climate change.

Our fate – and that of countless other species – rests on how effectively we are going to be able to juggle sets of often-conflicting priorities.

THE PROSOPIS EXPERIENCE

ONE genus that contains some aggressive plant invaders that have become especially problematic in many regions, both sub-tropical and tropical, is **Prosopis**. The *Prosopis* genus (of the Legume Family, Fabaceae) includes more than 40 species. Most, known commonly as **Mesquite**, are native to the Americas, having home ranges between Argentina or Chile in South America and the southern United States.

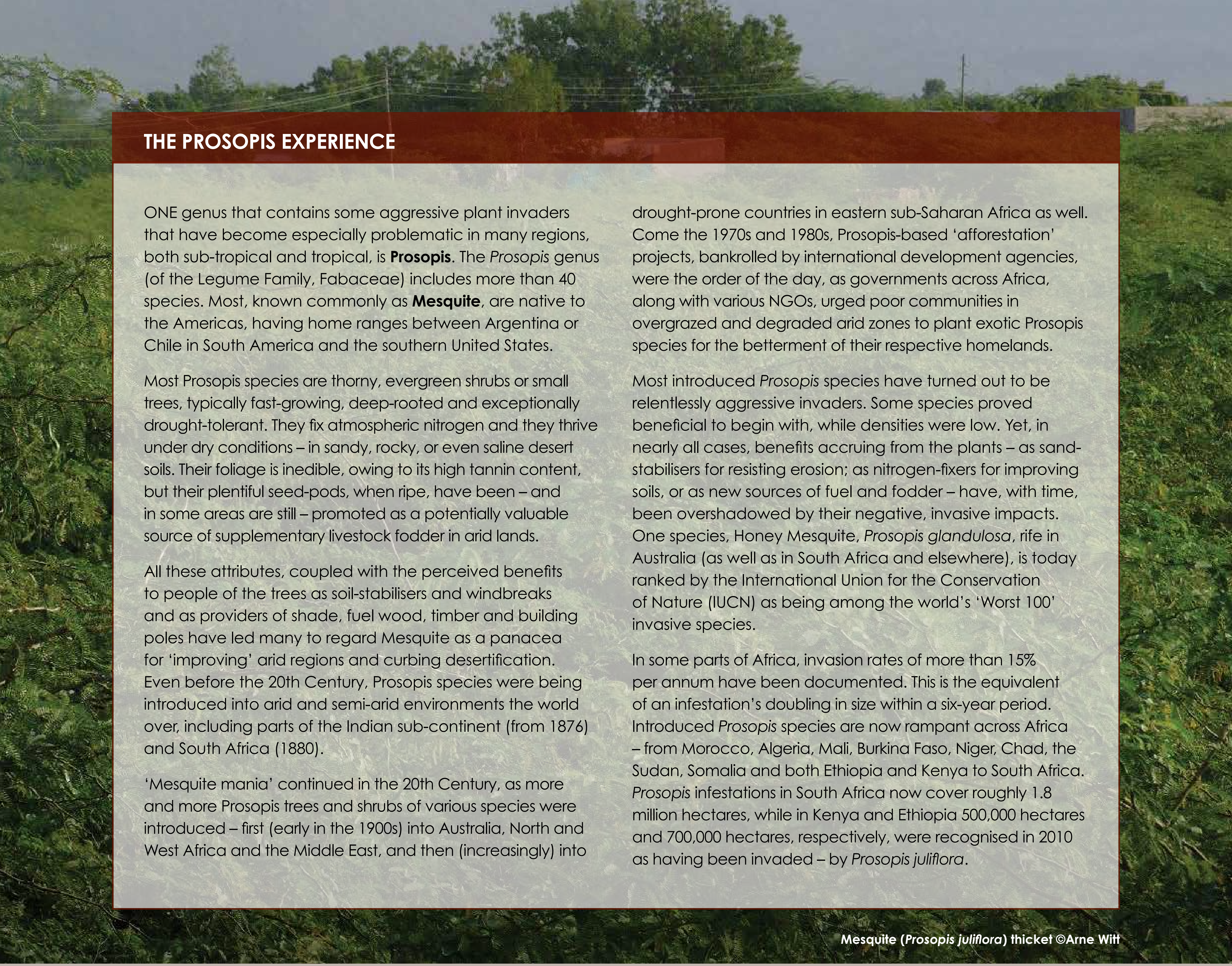
Most Prosopis species are thorny, evergreen shrubs or small trees, typically fast-growing, deep-rooted and exceptionally drought-tolerant. They fix atmospheric nitrogen and they thrive under dry conditions – in sandy, rocky, or even saline desert soils. Their foliage is inedible, owing to its high tannin content, but their plentiful seed-pods, when ripe, have been – and in some areas are still – promoted as a potentially valuable source of supplementary livestock fodder in arid lands.

All these attributes, coupled with the perceived benefits to people of the trees as soil-stabilisers and windbreaks and as providers of shade, fuel wood, timber and building poles have led many to regard Mesquite as a panacea for 'improving' arid regions and curbing desertification. Even before the 20th Century, Prosopis species were being introduced into arid and semi-arid environments the world over, including parts of the Indian sub-continent (from 1876) and South Africa (1880).

'Mesquite mania' continued in the 20th Century, as more and more Prosopis trees and shrubs of various species were introduced – first (early in the 1900s) into Australia, North and West Africa and the Middle East, and then (increasingly) into drought-prone countries in eastern sub-Saharan Africa as well. Come the 1970s and 1980s, Prosopis-based 'afforestation' projects, bankrolled by international development agencies, were the order of the day, as governments across Africa, along with various NGOs, urged poor communities in overgrazed and degraded arid zones to plant exotic Prosopis species for the betterment of their respective homelands.

Most introduced *Prosopis* species have turned out to be relentlessly aggressive invaders. Some species proved beneficial to begin with, while densities were low. Yet, in nearly all cases, benefits accruing from the plants – as sand-stabilisers for resisting erosion; as nitrogen-fixers for improving soils, or as new sources of fuel and fodder – have, with time, been overshadowed by their negative, invasive impacts. One species, Honey Mesquite, *Prosopis glandulosa*, rife in Australia (as well as in South Africa and elsewhere), is today ranked by the International Union for the Conservation of Nature (IUCN) as being among the world's 'Worst 100' invasive species.

In some parts of Africa, invasion rates of more than 15% per annum have been documented. This is the equivalent of an infestation's doubling in size within a six-year period. Introduced *Prosopis* species are now rampant across Africa – from Morocco, Algeria, Mali, Burkina Faso, Niger, Chad, the Sudan, Somalia and both Ethiopia and Kenya to South Africa. *Prosopis* infestations in South Africa now cover roughly 1.8 million hectares, while in Kenya and Ethiopia 500,000 hectares and 700,000 hectares, respectively, were recognised in 2010 as having been invaded – by *Prosopis juliflora*.



Mesquite (*Prosopis juliflora*) thicket ©Arne Witt

The continuing destructive impacts are incalculable. In eastern Africa, instead of developing into useful trees, *Prosopis juliflora* has formed sprawling, impenetrable thickets of low, shrubby multi-stemmed plants that provide only limited shade, while offering little by way of wood for building or for making charcoal. The plants have invaded riverbanks and seasonal watercourses. They are extremely thirsty plants, having tap-roots that rank among the deepest-penetrating in all of the Plant Kingdom. (In Tucson, Arizona, *Prosopis juliflora* roots have been found plumbing depths of more than 50 metres.) The plants also have an extensive lateral root system. So, while Prosopis may, in one way, have helped to stitch up soils and to halt advancing desertification; in another, the plants have created new 'green deserts' through depleting precious groundwater reserves in water-scarce environments, lowering the water-table and starving useful native trees such as the Umbrella Thorn, *Acacia tortilis*, and the Doum Palm, *Hyphaene compressa*.

Prosopis produces seed-pods in prodigious numbers. In one year and within a single hectare of Prosopis-infested habitat, pods holding as many as 50 million seeds have been recorded. Mesquite seeds are easily dispersed in flowing water, particularly during floods, which may carry the pods far from their mother plants. Animals also disperse the seeds after feeding on the ripe pods. The hard-coated seeds are softened as they pass through an animal's gut. This helps them to germinate. The dung in which seeds are deposited provides a ready source of nutrients for the growing seedlings. Seeds that do not germinate immediately may lie dormant on the ground for as long as 10 years. Mesquite also coppices readily on being cut down.

Thickets of invading Prosopis have replaced grasses and other native plants, greatly reducing livestock-carrying capacities on traditional pasture rangelands in Africa. In invaded parts of Ethiopia, Kenya and Somalia, pastoralist communities have been forced into covering ever greater distances in order to find enough grazing and browse for their herds. Prosopis encroachment on settlements and villages has forced some farming communities to abandon their land and to move elsewhere, bringing them into conflict with other communities.

In Kenya, where the dominant Prosopis invader, *Prosopis juliflora*, is known as Mathenge (after the Government forester, long since retired, who first promoted the species' introduction), there was a much-publicised lawsuit in July 2006, during which a live yet toothless goat was paraded before bemused High Court judges in Nairobi. The suit, filed by the Marigat community from Kenya's then-Baringo District, was levelled against the Kenya Government over adversities allegedly inflicted on the community and its livestock (hence the ailing goat on display) by *Prosopis juliflora*. Damages for which compensation was being sought included livestock deaths and debilitation, water and pasture losses, displacement of and injuries to people (inflicted by the plants' fiendish thorns), and restricted access to watercourses and riparian lands.

The court case harked back to the introduction, during the 1980s, under the Baringo Fuelwood Afforestation Extension Project advocated and funded by the UN Food and Agriculture Organisation (FAO) in association with Kenya's then-Forest Department, of *Prosopis juliflora* to large areas of the afflicted district.

What appears to have happened in the case of the toothless goat is that fibres from the young, green pods, which can be toxic if ingested in large quantities, and which are also very rich in sugar, had become lodged between the animal's teeth, causing inflammation of the gums and eventual tooth loss. At the time, the goat on display was said to be just one of many in the District suffering from this condition. Unable to browse, toothless goats are doomed, the community claimed, and have to be killed (and yet, ironically, many of the plaintiffs had, as active participants in the original 'land improvement' project, themselves been instrumental in helping to plant the accursed weed).

Mesquite is among the most conspicuously vigorous of all invading alien plants. After having colonised run-off niches on roadsides in NE Kenya and Ethiopia, it has grown so profusely as to spill out over the roads, which in places have been reduced to narrow passageways. On the road from Garissa to Hola, for example, on the west bank of Kenya's largest river, the Tana, there are places where the aggressive root systems of flanking *Prosopis juliflora* shrubs are, literally, eating into the edges of the thin strip of tar, lifting and cracking the asphalt. Sections of this road are now lined on both sides with a band, 15–20 metres wide, of solid Mesquite thicket, which continues to advance apace into the outlying Acacia–Commiphora woodland and bush.

The Tana River is a major conduit for the dispersal of Prosopis pods and seeds, and riverine habitats (some protected areas included) between the town of Garissa, on the river, which has been heavily invaded, and the Tana Delta, near Malindi on the Kenya Coast, are all suffering as a result. The Arawale National Reserve across the river from Hola is just one example. This reserve was established in 1974 as a refuge and breeding ground for the critically endangered Hirola Antelope, *Beatragus hunteri*. Since then, however, habitat change – induced in part by invading Prosopis – has rendered the habitat unsuitable. Most of the endemic grazing antelopes have moved to other areas further to the south and east, where (alas) they have no formal protection.

The Tana River Primate National Reserve, further down the river, supports the only populations of two critically endangered endemic primate species – the Tana Mangabey, *Cercocebus galeritus*, and the Tana River Red Colobus, *Piliocolobus rufomitratus*. This reserve too is being invaded by Prosopis. Other National Reserves in Kenya where Prosopis is spreading fast include Bogoria, Samburu, Shaba and Marsabit. In Ethiopia, *Prosopis juliflora* has invaded the Awash National Park, east of Addis Ababa, until now one of only a few places where Soemmerring's Gazelle, *Gazella soemmerringi*, an antelope species endemic to the Horn of Africa, can easily be seen.

Prosopis juliflora **thicket in Ethiopia ©Arne Witt**

Already, we know that the spread of invasive alien species – that of alien plant invaders especially – has become one of the most powerful drivers on the planet of *both* declining biodiversity *and* diminished food-production capacity. We know, too, that declines on both counts are rapidly increasing. Clearly, one way out of this bind is to optimise our food-production and water-use efficiencies, so we might alleviate unsustainable human pressure on beleaguered natural ecosystems and thus pre-empt needless further destruction of biodiversity for what, today, are largely wasteful land uses. At the same time, we are going to have to redouble efforts to protect precious remaining wild ecosystems from further non-human encroachment as well.

Either way, steps are going to have to be taken to counter the serious and growing threat posed by the continuing global spread of invasive alien species – of plants in particular. The nature, and extent, of humanity's response so far to this most daunting of challenges is the subject of the following chapter …

Bulahar in Somalia – abandoned as a result of Prosopis infestations ©Jan Breithaupt

Prosopis juliflora encroaching on homes in Ethiopia ©Arne Witt

Responding to alien invasions

Steps that can – and are – being taken to eradicate, contain, or control the spread of existing infestations of invasive alien plant species, in order to limit their increasingly destructive impacts …

Invasive alien species have been damaging natural environments and making our lives difficult for hundreds of years. Both the extent and the impact of their spread have increased alarmingly over recent decades, however. As rival exploiters of vital ecological resources and ecosystem services in all of the habitats we ourselves have colonised around the world, such species are a persistent and growing threat to our food security and to the health and economic well-being of our societies. Eradicating these unwelcome alien competitors and fellow despoilers has therefore become our most fervent wish.

Eradication though, especially regarding plants, has in most cases remained just that – a wish. To eliminate, from any substantial area, the entire population of any well-established invader is seldom an achievable goal. In the case of an alien plant invasion, eradication entails the systematic elimination over time of every individual plant of the invading species, until it can be ascertained that no new plants, and no viable seeds or other propagules (including roots, shoots, suckers, or other detached parts which, depending on the species, may be capable of developing into new plants) either, remain in an area.

Understandably then, eradication generally succeeds only where a plant invader's presence is detected early – before the species can spread beyond the immediate area into which it was introduced. Even then, the success of an eradication campaign will depend on there being a rapid and well-organised response, complete with thorough and sustained follow-up actions and monitoring procedures. Such operations need to be planned and budgeted for, as the follow-up measures may have to extend well into the future.

Large-scale eradication campaigns are seldom undertaken for invasive plants, as these are extremely costly and have to be sustained over long periods. There is always the risk, moreover, that such a campaign, no matter how well funded, might fail. One eradication effort, under way for more than 55 years and only now on the verge of succeeding, is the campaign in North America to eliminate the Witch Weed, *Striga asiatica* – an invader that grows parasitically on the roots of maize, sorghum, rice, millet, sugar cane and other grasses, causing steep declines in crop yields. Since its inception in 1956, this campaign alone has cost the United States in excess of US$ 300 million.

Over this time, a Striga infestation of 200,000 hectares of farmland spread across 20,000 km² of the Carolinas, North and South, has been reduced to patchy occurrence only within an area of no more than 2,000 hectares. Initially, soil-applied herbicides were used. Ethylene gas was later found to be effective in preventing the regeneration of the root-parasites. While other nations may baulk at the costs and the logistics involved, the benefits – amounting to more than US$ 25 billion annually in the value of restored agricultural productivity – have, from a US standpoint, rendered the ongoing eradication effort an eminently worthwhile investment.

The success of some other US alien plant eradication campaigns still hangs in the balance. Early detection in 1995, in one South Carolina pond, of an infestation of the notoriously aggressive aquatic fern *Salvinia molesta*, from Brazil, otherwise known as Giant Salvinia (or Kariba Weed), prompted a rapid eradication response on the part of state and federal authorities alike. The resulting campaign appeared, come 1996, to have succeeded. Manual clearing and mechanical dredging, combined with the use of herbicide sprays, eliminated the worrying infestation – and the authorities breathed a collective sigh of relief.

The relief would prove short-lived, however, for the weed, which spreads rapidly, forming thick, choking mats covering entire water bodies, went on to appear in Texas (in 1997) and has since also spread to wetlands, dams and lakes in North Carolina and other southern US states. Introduced via the aquarium trade, the free-floating weed is a familiar invasive menace in many countries. In the reservoir of the Kariba Dam, on the Zambezi River between Zimbabwe and Zambia in southern Africa, Giant Salvinia had, as long ago as 1963 (within five years of completion of the dam's construction), covered more than 20% of the impounded water's 5,400-km² surface area. Hence the weed's alternative common name, Kariba Weed.

Infestations of Salvinia – in mats that are sometimes up to a metre thick and which may embody as much as 400 tonnes/hectare of biomass – impede boat traffic, block access to water, clog irrigation piping, impair the function of hydro installations, and disrupt fisheries. Salvinia infestations suffocate and replace native aquatic vegetation, reducing underwater light penetration and preventing oxygen transfer, making aquatic habitats unsuitable for fish and other animals. Amid fears in the US that eradication of Giant Salvinia might no longer be possible (despite the rapid and promising early response), the focus today of the US war on *Salvinia molesta* has shifted from one of eradication to one of containment.

Containment

A containment response – designed to restrict an invading species to a particular zone – is an essential first step towards eventual eradication. Again, containment is usually possible only where the presence of an invader is detected early. Australia's response to the detection in 1994, near Queensland's Tully River, of Siam (Triffid) Weed, *Chromolaena odorata*, a noxious invader from Central and South America, is often cited as a model of effective containment. Chromolaena had not appeared in Australia before, but its destructive impacts elsewhere in the world, as an invader of pastures, farmlands and wilderness areas, had been widely documented. So the species' arrival was anticipated. Chromolaena was a declared noxious weed in Australia even before it turned up. Crucially, this level of preparedness made early detection more likely.

A five-year Chromolaena eradication programme was promptly launched, with an annual operating budget amounting to the equivalent of US$ 175,000. Herbicides that had been used effectively elsewhere for controlling the plants were hastily registered and deployed. Containment measures taken to stop the plants from spreading included a massive public awareness campaign in the popular media, on television and at the community level. This enabled people from all walks of life to identify the species and to report sightings, outside the containment area especially. Chromolaena is notoriously hard to contain, as its tiny, light-weight seeds, produced in great abundance, are dispersed freely by wind or in water, by animals or by people and their vehicles. All pathways for potential spread were duly publicised.

Even so, Chromolaena Weed has still not been eradicated from Queensland. The infestation, though, has been brought under control. Isolated plants that occasionally appear have, except for one lone plant, all been found within the original containment zone. Now, it is possible manually (by hand-pulling) to root out these few stragglers. The containment exercise has saved Australia millions of dollars annually in grazing losses and lost crop production. As the weed is highly flammable, its containment has also averted a potentially serious added fire hazard in forested habitats that spreading infestations might otherwise have colonised. While the containment war goes on, the public awareness generated may yet prove crucial in enabling Australia to repel likely future Chromolaena invasions.

Containment has a long history. Noxious Weed Laws, now reflected on the statute books of most countries, came into being in the 19th Century out of a need to contain the spread of invasive plant species that were undermining agricultural production or poisoning livestock animals. As early as 1860, in one of the first ever Noxious Weed Laws, the Spiny Cocklebur, *Xanthium spinosum*, a South American annual herb, was declared a noxious weed in South Africa's then Cape Province. Not only does this species invade croplands; the young plants are also toxic to livestock, and the female flower-heads (burs) of adult plants cling to and 'foul' the wool of sheep. A Provincial Weed Inspector, hired to enforce the legislation, was empowered (amid efforts to contain the weed's spread) to halt the movement of bur-carrying animals.

A common target of some of North America's earliest Noxious Weed Laws was the Musk Thistle, *Carduus nutans*, a prolific Eurasian invader of pasture rangelands. In Canada's Manitoba Province, under the provisions of a Noxious Weeds Bill first enacted in 1871, District Weed Inspectors could hand down stiff penalties to farmers whose produce, on being checked on railroads, was found to be contaminated with thistle seeds. The inspectors were further empowered to order the razing of infested crops and the burning of infested pastures. The containment effort failed, however, and

Musk Thistle (*Carduus nutans*) a menace to North American farmers ©iStockimages

today the Musk Thistle remains a menace across much of North America.

By the late 1930s, Noxious Weed Laws had been enacted in most US states. Nationwide legislation there would follow only in 1975, however, when the US Department of Agriculture's Federal Noxious Weed Act (superseded in 2000 by the Plant Protection Act) came into effect. By then, Noxious Weed Acts had been passed in most countries. Numbers of nationally declared Noxious Weeds around the world have risen sharply over recent decades, from fewer than half a dozen species in the case of some nations to well in excess of 50 today. Yet, members of the general public in many nations would be hard pressed to name, much less identify, any more than a few of the species classified by their governments as Noxious Weeds. Many of today's Noxious Weed Laws, then, being un-enforced and so unbeknown to people, are of little practical value as vehicles for containment.

Control

Where invasive alien species have already spread over very large areas, eradication and containment are seldom feasible as management options. Control, in conjunction with restorative habitat management, may then be the only realistic recourse. The aim of a control programme is to reduce the abundance and density of infestations, and to keep harmful impacts of an invasion down, as far as possible, to within manageable limits. The effective control of widespread infestations usually calls for an integrated approach combining manual, mechanical, chemical and biological methods.

Manual and **mechanical control** methods involve the removal – by hand, or with tools, implements, or machines – of an infestation's individual invaders. Controlling alien plant invasions manually may include hand-pulling, uprooting, hoeing, felling or cutting back. Such methods can be labour-intensive, but in regions where manual labour is readily available and can be hired cheaply manual control is often both effective and economical. Ring-debarking (girdling) may also be effective, albeit only for eliminating woody invaders of species that do not coppice.

Most manual control methods have the added advantage of being wholly target-specific. Repeated follow-up control operations are generally required, however, and subsequent rehabilitation measures are essential, as disturbed ground and soil erosion in cleared areas may encourage re-invasion. Manual control alone is seldom entirely successful against large-scale infestations. Mechanical interventions using bulldozers or tractor-drawn ploughs or other machines to clear extensive weed infestations have the obvious drawback of being indiscriminate and of razing non-target plant species as well, while at the same time creating conditions that may be ripe for re-invasion.

In Lake Victoria, mechanical efforts to keep the abundance and the impacts of the Water Hyacinth, *Eichhornia crassipes*, at bay have failed repeatedly. Even heavy-duty harvesting machines, imported in the 1990s and capable of clearing 40 tonnes of the weed in an hour, have proved ineffective. Sustained manual clearing on a small scale has nevertheless helped lakeshore communities to limit the local impacts of the invasion. Floating booms, meanwhile, have helped to exclude mats of the weed from some localities, shielding the Nalubaale (Owen Falls) hydro-electricity plant on the upper White Nile for instance, while facilitating follow-up mechanical management interventions.

Chemical control methods, involving the judicious use of approved herbicides, can improve the efficacy of manual and mechanical clearing activities. Applying systemic herbicides to cut tree-stumps or to incisions made in the bark of trees or shrubs (in a procedure known as frilling) will, on spreading through the vascular tissue of treated invaders, eventually kill the targeted trees or shrubs. Basal stem applications and stem injections have the same effect. These applications are very target specific with no discernable non-target impacts.

Clearing Lantana – Victoria Falls ©Michael Nang'alelwa

Foliar sprays of herbicides such as glyphosate are widely used to control invasive plant infestations – those of herbaceous plants and the seedlings of woody invaders in particular. Herbicidal sprays, applied using portable 'pack' sprayers, offer a fast and effective means of control, yielding rapid results. Where chemical treatments can be administered topically to individual plants, the risks of inflicting collateral damage – detrimental impacts on non-target species, always a danger with herbicides – can be minimised. Many herbicides are non-selective in their action, so particular care has to be taken over their application.

Drawbacks associated with chemical control, other than potentially harmful side-effects on the broader ecology of ecosystems include the high costs of the chemicals. The prohibition in many countries of the use of herbicides in protected areas is another limitation. There is the added risk, over time, that some of the targeted invaders might build up a resistance to certain chemical control agents, particularly in cases where a herbicide is applied incorrectly or is used repeatedly in the same locality over an extended period. This has been a problem in some cropland areas, where recourse to stronger and more lethal treatments has in some cases led to an escalation of what has been described as the 'toxic treadmill'. That said, the correct use of herbicides to control environmental weeds is widely acknowledged, in most parts of the world, as being extremely effective with negligible non-target impacts. This is especially so in developed countries where the costs of labour are prohibitive.

Biological control (biocontrol) has in recent decades gained acceptance in many countries as the most cost-effective and reliable means of managing large infestations of invasive alien plant species. Biocontrol involves the deliberate, closely-monitored introduction of one or more species of highly specialised alien organisms that hail from the original home range of the invading plant species, and which physiologically are adapted to feeding exclusively on or attacking exclusively plants of that species.

The introduced host-specific organisms are generally insects, mites, or pathogens (mainly fungi). These are organisms that in the homelands of the plants keep their growth in check. And it is in the absence of these natural enemies that the plants, in their adoptive homes, where they encounter no such enemies, are able to explode into abundance – and become invasive. Control organisms of more than one species may be introduced, each for its role in attacking a different part of the targeted invasive species. Biocontrol does not eradicate the alien plant invader, but rather weakens its competitiveness with native plant species, suppressing its density and environmental impacts, so allowing the native vegetation to recover.

There have, in the past 100 years, been some remarkable biocontrol successes in combating alien plant invasions. In 1913, infestations in South Africa of the Prickly Pear, *Opuntia monacantha*, were brought under control with the help of the introduced Wild Cochineal Insect, *Dactylopius ceylonicus*, from Brazil, which was imported via India and Sri Lanka. The insects attach themselves to the cladodes (stem-pads) of the cacti and suck moisture from the plants. In the 1920s, the larvae of the Cactus Moth, *Cactoblastis cactorum*, introduced from Argentina, were instrumental in controlling the vast *Opuntia* infestations that had taken over more than 25 million hectares of the Australian outback. The moths lay their eggs on the cactus spines. Their black-and-orange-striped caterpillars bore into the cladodes, devouring the cacti from within.

More recently, two South American weevil species – *Neochetina eichhorniae* and *N. bruchi*, both introduced into Lake Victoria in 1997 – succeeded, within ten years, in reducing the extent of the lake's Water Hyacinth infestation by nearly 85% – from a peak of roughly 20,000 hectares to little more than 3,000 hectares in 2006. Both are species that in the hyacinth's home range feed on and inhibit the growth of the plants. The adult weevils eat the hyacinth leaves. The larvae, more damagingly, eat their way down the petioles and into the crowns of the plants. Nutrient-rich sediments swept into the lake since 2006 have, in places, enabled the hyacinth to recover, however. Here, as elsewhere in Africa, the South American weevils have proved ill-adapted to highly eutrophic conditions.

The advantages of biological control are that populations of the introduced control organism or organisms – once established – are a permanent, self-sustaining presence. So there are no associated running costs. A biocontrol organism's self-perpetuating populations become established, moreover, throughout an infestation of the targeted invasive plant species, infiltrating infested areas that may be inaccessible to chemical or mechanical control interventions. Abrupt habitat disturbance (often a drawback with convemtional control methodologies) can be minimised, and there are no toxic chemical residues left behind. The specificity of a control organism's dependence on just one host plant species (the invader) means there is no risk either of damage to plants of other species or to ecosystems more generally.

The cost of a biocontrol programme – a one-off investment – is also much lower than that of programmes based on other approaches, which in addition may call for recurrent expenditure. In integrated control programmes employing a combination of different approaches, biocontrol may significantly reduce the costs of the associated manual, mechanical and chemical components. In South Africa, the use of biocontrol agents has reduced expenditure on mechanical and chemical control measures nation-wide by as much as 20%. Further reductions, amounting to an overall cost saving of more than 40%, are envisaged, as the practice of biological control becomes more prevalent in integrated invasive plant management in South Africa.

Benefit–cost analyses in both South Africa and Australia show consistently high returns on investment for biocontrol. In the case of *Lantana camara*, a benefit–cost ratio of 35:1 has been achieved in South Africa on biocontrol programmes using a range of introduced organisms, including leaf-

The sap-sucking bug, *Teleonema scrupulosa*, is having a significant impact on *Lantana camara* in Zambia

mining beetles (such as *Uroplata girardi*), sap-sucking bugs (notably the Tingid, *Teleonemia scrupulosa*), and leaf-, flower- and seed-feeding species of moths and flies. This means that for every one dollar that is spent on the biological control of Lantana, benefits amounting to US$ 35 (in the value of restored agricultural or livestock forage productivity and ecosystem health, as well as in savings in overall Lantana control costs) have accrued.

In Australia, the average national benefit–cost ratio for all biologically controlled noxious weed infestations currently stands at about 24:1. An annual net return from biocontrol programmes amounting to the equivalent of more than US$ 100 million is anticipated within the next 15–20 years – if biocontrol programmes there continue to be expanded at the present rate. Roughly three-quarters of this return is expected to be reflected in agriculture-related gains.

From a purely economic standpoint then, strong arguments can be made in favour of biological control. For many nations, the costs of other forms of control – manual, mechanical, or chemical – are prohibitive, given the massive scale of the infestations requiring attention. Costs of mechanical control in the United States range from about US$ 900/hectare/year for terrestrial weeds to more than US$ 20,000/hectare/year for some aquatic weeds. Water Hyacinth management was until recently costing Nigeria US$ 639/hectare/year in mechanical control, and US$ 161/hectare/year in chemical control. The cost in South Africa, over a fifteen-year period, of manually, mechanically and chemically clearing infestations of various invasive plant species from areas spanning millions of hectares was US$ 457 million and yet invasions appear to have increased, and remain a serious threat, in many biomes.

Yet there is still reluctance in some quarters – and among conservation authorities especially – to embrace biocontrol as a means of managing alien plant infestations. The deliberate introduction of alien species into protected areas is in any case against the law in many countries. No law, though, has been able to stop invasive species from getting into conservation areas anyway, either of their own accord or though accidental or even deliberate dispersal. The moral distinction, then, between accident and design is becoming increasingly 'academic' and irrelevant, some would argue.

Other reservations with regard to biocontrol may stem, in part, from the disastrous and lingering repercussions of deliberate introductions made in the past of non-plant-related 'control' species that in some instances went on to become menacing invaders themselves. The introduction into Australia in 1935 of the now-infamous Cane Toad, *Bufo marinus*, from the tropical Americas, is one such case. The Cane Toads were introduced to control native Australian Cane Beetles, *Dermolepida albohirtum*, which had been damaging exotic sugar-cane plantations in the state of Queensland.

As generalists (non-specialist predators), the toads found other prey more to their liking. They multiplied and spread rapidly – there are now more than 200 million of these amphibians in Australia. A toxic parotid secretion protects them from all native predators, which have evolved no defence against such alien poisons. Over the course of their advance, the alien toads have out-competed, outnumbered and ousted many native Australian insectivores, while showing no apparent interest in the Cane Beetles whose populations they were brought in to control.

The days of using introduced alien generalists to control the infestations of other introduced alien generalists are long over, at least officially. The release on islands of Domestic Cats, mongooses and other indiscriminate killers to control problematic rat infestations may have been biocontrol's earliest mistake. The last great fiasco of this kind was the release in 1955, on Hawaii (and later on Mauritius and other islands), of the Rosy Wolf Snail, *Euglandina rosea*, from tropical North America. As a ruthless predator on other snails, the hope was this species might eliminate the infestations of another alien mollusc species – the invasive Giant African Snail, *Achatina fulica*, a serious crop pest that had been introduced earlier (in the 1940s) as a prospective food resource.


The Cane Toad (*Bufo marinus*) has wreaked havoc in Australia ©iStockimages

Again, as generalists, the Rosy Wolf Snails found other prey far more appealing – and so plentiful they too became an invasive menace. On Mauritius, they have been responsible for the extinction of at least 24 of the island's 106 endemic snail species. There, as on Hawaii and elsewhere, they have had little impact on the Giant African Snails they were brought in to control.

Today, only target-specific biocontrol agents are considered. Imported organisms identified as potential candidates for release into new environments under biocontrol programmes are screened in quarantined laboratories where all contaminants, such as parasitoids and pathogens are initially removed, prior to undertaking trials to confirm their host-specificity. The tests are very stringent and may take as long as five years to complete. In that time, it must be confirmed that a proposed biocontrol agent cannot survive on a diet of any locally occurring plant species (either native or introduced) other than the targeted plant invader. The research and testing procedures are costly, but then, once a biocontrol agent is verified as being effective and ecologically safe in one affected region, the costs of its further testing and eventual release into other regions may be significantly lower.

In Australia, screening was carried out on 15 potential biocontrol agents, at a cost of approximately US$ 21 million, for possible use in the management of infestations of the Giant Sensitive Plant, *Mimosa pigra* – a prickly shrub from the tropical Americas that has invaded floodplains and wetlands there, as in many other regions of the world. The moth *Carmenta mimosa*, whose larvae bore into the stems of the plants, causing them to die, emerged as one of the more promising candidates. Only when its impact and host specificity was demonstrated in laboratory trials was the alien Central American moth introduced into Mimosa-infested areas in Australia, where today it is reportedly living up to its promise.

The cost, in further screening prior to release, of introducing *Carmenta mimosa* into a country such as Zambia – whose government has already spent more than US$ 500,000 on mechanical and chemical control of Giant Sensitive Plant on 800 hectares of invaded floodplain – would be of the order of US$ 35,000 (depending, that is, on how many plant species and crop varieties the national authorities there might insist on having screened in quarantine.) The outlay, in any event, would be far lower than the costs to Australia of carrying out the initial research on the agent in question.

The effectiveness of a biocontrol agent may vary from region to region, and there is always the possibility that an organism used effectively in one place may not 'take' (either survive, that is, or become established) in another. In some cases, it may take an introduced biocontrol agent many years to settle in a new environment, despite the ready and plentiful supply of food. The *Aphthona* Flea Beetle, widely introduced in North America in the late 1980s to control Leafy Spurge, *Euphorbia esula*, a prolific Asian plant invader of US pasture lands, took almost ten years to become established in some infested areas. It turned out that the Flea Beetles were inhibited by the cooler weather. A sudden change in environmental conditions, moreover, may dramatically reduce the effectiveness of even well-established biocontrol organisms.

Like the plant species on which they are uniquely adapted to feed, such organisms have evolved a number of different biotypes. A species' climatic and environmental tolerance may vary from one biotype to another. So a biocontrol agent of a strain that has co-evolved in association with one particular biotype of a targeted plant species may not survive on plants belonging to another biotype of the same host species. For example, some organisms – including the gall-forming fly *Cecidochares connexa*, used successfully in many countries in South East Asia for the control of Siam Weed, *Chromolaena odorata*, failed to establish on potted Chromolaena plants in quarantine in South Africa, because the Chromolaena biotype present in South Africa differs from that which occurs in South East Asia. Such is the degree of specialisation shown by some of these host-specific organisms.

Biological control still has its critics, and its practice is by no means universally endorsed. Persistent fears that introduced biocontrol organisms might have potentially dire unforeseen consequences have so far proved largely unfounded, however. Under today's strict safety protocols, set out in the International Plant Protection Convention (IPPC) *Code of Conduct for Import and Release of Exotic Biological Control Agents*, the margin for error has been reduced considerably. The use of unsuitable biocontrol agents, of the kind introduced informally in the past, often at the behest of influential farming lobbies, is now far less likely.

Restorative habitat management

No response to an alien plant invasion – whether the response is one of eradication, containment, or control – is complete without follow-up rehabilitative actions. Stands of an invasive species that are removed or killed need to be replaced with plantings of non-invasive or benign species (and preferably with a variety of native species) that will help restore the natural integrity and productivity of the whole ecosystem, while strengthening the land's ability to resist re-invasion – by the same or by other species of invasive alien plants.

All too often, removal of an alien plant infestation is viewed as an end in itself, when instead this should be seen as just the beginning of the most important phase of all – that of rehabilitating a landscape. The restoration process may take many years, and should be carried out in tandem with follow-up procedures designed to eliminate or exclude re-invasions. Little by little, with judicious grazing and fire management regimens on recovering pastures, native grasses and herbs may regain the ascendancy. Native species of pioneer shrubs and trees, present in the seed-bank or re-planted in degraded forests and bush lands, may gradually gain the upper hand. Degraded soils may recover. Rehabilitated wetlands may, through filtering out pollutants, restore the natural health and vitality of invader-friendly eutrophic environments. Rehabilitated watersheds and riverbanks may restore precious channels of clean water supply.

Without such rehabilitative actions, areas cleared of invaders may rapidly become re-infested – and at densities, often, that are even greater than was the case before. An integrated invasive alien plant management programme, therefore, should be planned in phases that make follow-up rehabilitation realistically achievable. Where too large an area of infestation is cleared all at once, effective follow-up may not be feasible.

Given the resources needed, and given the associated costs – in time, as well as money – of sustaining effective integrated programmes to control alien invasions and so limit their damaging ecological, social and economic impacts, there is one obvious conclusion to be drawn. Namely: that we should try, wherever possible, to *prevent the arrival in the first place* of an invasive alien plant species …

Clearing *Mimosa pigra* in Zambia's Lochinvar National Park proved to be prohibitively expensive, increasing calls for the introduction of host specific and damaging biocontrol agents ©Arne Witt

BIOLOGICAL CONTROL AGENTS

IT is in the absence of natural enemies that some plant species, on being introduced into a new environment, are able to explode into abundance – and become invasive. Having no organisms feeding on them, or sapping their vigour, or reducing their reproductive potential, such species have a huge competitive advantage over the native plant species of the habitats they colonise. The native plants do all have natural enemies that daily keep their growth in check – just as an invader would, back on its own home turf.

The aim of biological control, then, is deliberately to introduce – into the infestations of an invasive alien plant species – one or more of that plant species' natural enemies as well, from its original homeland. For safety reasons, only host-specific enemy organisms, of species which are physiologically adapted to feeding exclusively on or to attacking only plants of that species, can be considered. Most such organisms are insects, mites, or pathogens (mainly fungi).

No enemy organism can be released until its ecological safety has been established through a process of rigorous testing carried out in quarantined laboratories under the strict protocols laid down in the International Plant Protection Convention's Code of Conduct for Import and Release of Exotic Biological Control Agents. All contaminants, including parasitoids and pathogens, are removed from all prospective control agents prior to undertaking trials to determine their host-specificity. Only after it has been confirmed that a proposed agent is safe, and cannot survive on a diet of any locally occurring plant taxon (either native or introduced) other than the targeted plant invader, is such an organism released.

A biocontrol agent does not eradicate the targeted alien plant invader, but rather weakens its competitiveness with native plants, suppressing the invader's density and vigour and reducing its environmental impacts, so helping the native vegetation to recover. One advantage of biological control is that populations of the introduced control organism or organisms, once established, are a permanent, self-sustaining presence. So there are no associated running costs. A biocontrol agent's self-perpetuating populations become established, moreover, throughout the infestation of a targeted plant invader, infiltrating infested areas that may not be accessible using manual, mechanical or chemical control methods.

The cost of a biocontrol programme – a one-off investment – is also much lower than that of programmes based on other control approaches, which may also call for recurrent expenditure. In integrated programmes combining different methods, biocontrol may significantly reduce the costs of associated manual, mechanical or chemical interventions. A biocontrol programme also ensures that control can be achieved gradually, without the ecological 'shock' that may occur when an infestation is cleared or killed abruptly, leaving fallow land that is susceptible to further degradation and rapid re-infestation. Biological control can be effective too in resolving conflicts of interest, for example over beneficial, commercially valuable agro-forestry species that are also highly invasive. Agents that reduce the reproductive potential of invasive trees without affecting their growth enable control to be achieved without sacrificing economic prospects.

The specificity of a biocontrol organism's dependence on just one host species (the invader) means that there is no risk either of damage to plants of other species or to ecosystems more generally. Benefits can be reaped by multiple stakeholders, regardless of their financial status, or of whether or not they contributed to the initial research effort. Yet, while biological control may contribute significantly to the management of invasive alien plants of many species, it remains but one component of an effective overall management strategy.

Showcased here are just a few examples of biological agents that have proved effective in controlling alien plant infestations …

BEETLES

Two South American weevil species – *Neochetina eichhorniae* and *Neochetina bruchi* – have, between them, succeeded in considerably reducing the extent of Water Hyacinth infestations in many regions of the world. Both are species that in the hyacinth's home range feed on and inhibit the growth of the plants. The adult weevils eat the hyacinth leaves. The larvae, more damagingly, eat their way down the petioles and into the crowns of the plants. In Africa's Lake Victoria, the two weevil species, both introduced in 1997, succeeded within ten years in reducing the extent of the lake's Water Hyacinth infestation by nearly 85% – from a peak of about 20,000 hectares to little more than 3,000 hectares in 2006.

The leaf-mining beetle, *Uroplata girardi*, from Central and South America, has proved especially effective – in southern Africa and elsewhere – in retarding the growth and slowing the spread of *Lantana camara*. By feeding on the Lantana leaves, the introduced beetles impair the function of the shrubs, inhibiting their ability to produce flowers and fruits. Visibly damaged and discoloured Lantana foliage is often the result.

Two other beetles, *Algarobius prosopis* and *Neltumius arizonensis*, both introduced from Arizona in the US, have been used in South Africa for the control of Prosopis infestations. Both are seed-feeding species. Females lay their eggs on the seed-pods, and the larvae, after they

The South American weevil, *Neochetina eichhorniae* ©Anthony King

BIOLOGICAL CONTROL AGENTS

hatch, chew their way through the pods and into the seeds, on which they feed. There, the larvae pupate, having first tunnelled up to the surface of the pods and created 'trap-doors' from which the adult beetles can emerge. The adult beetles, able to fly over long distances, disperse widely through Prosopis-infested areas, but their effectiveness as biocontrol agents is compromised by the fact that animals eat many of the pods (and disperse the viable seeds) before the beetles can colonise them.

The seed-feeding weevil *Melanterius maculatus*, from Australia, has been used to control infestations of the Black Wattle, *Acacia mearnsii* – a useful plantation tree which, in many parts of the world, has also become an invasive menace. The weevils attack and destroy only the mature seeds, and so do not affect the trees themselves, or their timber or bark.

BUGS

The Lantana Leaf Mirid, *Falconia intermedia*, a species of sap-sucking bug, has been deployed in the battle to control infestations of *Lantana camara* in South Africa. Both the adult mirids and the nymphs feed on Lantana leaves, removing the chlorophyll needed for photosynthesis and creating white specks on the upper leaf-surfaces. Severe feeding damage can cause entire plants to turn silvery-white and to shed their leaves. This starves the shrubs of resources, limiting their capacity to produce flowers and new leaves or shoots.

MOTHS

The larvae of the Central American moth, *Carmenta mimosa*, have been found – in Australia – to be among the most effective biological agents for controlling infestations of the Giant Sensitive Plant, *Mimosa pigra*. The larvae of the moths bore into the stems of the plants, causing these to break off and die. The larvae of another Central American moth, *Pareuchaetes pseudoinsulata*, feed on the leaves of one widely introduced form of Triffid Weed, *Chromolaena odorata*; so these moths too are now used as agents in biocontrol programmes targeting Chromolaena infestations of this particular biotype.

Carmenta mimosa, biocontrol agent for *Mimosa pigra* ©Colin Wilson

The stem-galling fly, *Cecidochares connexa* ©Colin Wilson

FLIES

Various species of leaf-mining and stem-galling flies have been introduced to control alien plant infestations. The Herringbone Leaf-Miner, *Ophiomyia camarae*, for example, has been used to control infestations of *Lantana camara*. The larvae of the flies, hatching from eggs deposited in the veins of Lantana leaves, 'mine' the veins, preventing the movement of nutrients from the leaves to the rest of the plant. Use of the stem-galling fly, *Cecidochares connexa*, meanwhile, has been very successful in controlling *Chromolaena odorata* infestations in Indonesia.

Impact of a biocontrol agent, the gall-forming rust fungus, *Uromycladium tepperianum*, on Port Jackson Willow (*Acacia saligna*) in South Africa ©Alan Wood

Pre-empting alien invasions

How preventive measures that block the influx and dispersal of known plant invaders may provide the best line of defence

The old medical dictum to the effect that prevention is better than cure *is frequently invoked in relation to alien species' invasions – and with good reason. The maxim also has the ring of a despairing lament. Everywhere on Earth, we are paying a heavy price for the mounting toll in damage, ecological, economic and social, wrought by alien invasions that* might have been averted. *Huge amounts of our time and our money too are being ploughed, year after year, into efforts to limit the destructive impacts of invasions that* might have been averted. *We have learned then, to our great cost, that prevention would have been, and is, far better than cure.*

It may seem rather late in the day to start *preventing* the spread of some invasive alien species. For decades, centuries in some cases, via our transportation, trade and travel networks, alien invaders could enjoy unrestricted access to new environments. Like us, many are *already* well established in most of the more congenial habitats and regions on the planet. Putting down the shutters now, on ecosystems long since invaded, may seem like an opportunity already missed.

Preventive measures, though, focused on identifying and monitoring common invasive pathways and – wherever possible – blocking or restricting invader access, form an integral part of a successful invasive species' management campaign. Such measures are critical, not only in pre-empting the arrival of potentially damaging new invaders, but also in preventing re-invaders from reversing hard-won gains registered under existing management programmes. And besides, there are in most regions still extensive tracts of vulnerable habitat that, mercifully, have not been invaded.

Any effective pre-emptive strategy embodies two main components. First, such a strategy must provide for the **prohibition** of trade imports into a country or region of *unwanted species with known invasive proclivities*. These are usually species that in the past were introduced deliberately (into that country or region, or elsewhere), but which have turned out to be invasive. Species on the banned lists of different nations vary, depending – in each case, and from country to country – on the severity of the national threat each is seen to represent. Prohibition of trade in *useful but potentially invasive species that are not already present in a country* is based, as we shall see (pp. 67), on **risk assessment**.

Trade in any potentially invasive species should be guided by the Precautionary Principle, which holds that *where an introduced species' possible impacts (not just on commercial interests, but on wider ecosystems and societies as well) have yet to be established scientifically, international trade in such a species should be treated as a potential invasive risk, until proven otherwise*.

The second component of an effective pre-emptive strategy is **interception**. This may involve the apprehension of prohibited species in the process of being *smuggled* into a country or region. More often, interception involves the exclusion of *unwanted or prohibited species detected on the point of being introduced inadvertently*. Such species are often incidental contaminants of legally traded cargoes. They may also be hangers-on or stowaways on incoming flights, ships, or other carriers or vehicles. Or they may be passengers travelling with us on our clothing or footwear, or in our bags, or among our personal effects.

Contaminants present in incoming cargoes of traded plant material may include the seeds or other propagules (roots, shoots, suckers, or other detached parts which, depending on the species, may develop into new plants) of prohibited invasive alien species. Equally, they may include pest species of insects or of other invertebrates, or their eggs or larvae. Such contaminants may have eluded detection in the mandatory phytosanitary checks carried out beforehand in exporting countries, or they may be attached propagules or organisms lurking in, or on, the materials used for packaging the exported items.

The elimination of unwanted species, once detected, may involve the disposal or repatriation of contaminated cargo or freight before this can enter a country. Disposal charges and punitive fines are borne by the importers (or, in some instances, by the exporters) of consignments that are found to be contaminated. Suspect cargoes may be subjected to a routine process of **decontamination**. This may entail periods of compulsory quarantine or measures such as fumigation, heat-treatment, refrigeration, disinfection and irradiation. Strict enforcement of quarantine regulations can, along with application of effective treatment procedures, significantly reduce the chances of an alien invader's accidental entry and subsequent spread. Today, most ships and other international carriers are routinely decontaminated.

The same few vectors and pathways are used by whole rafts of invasive species. So, exclusion efforts are best focused, not on intercepting individual species, but on interventions designed to block entire avenues of spread. In 1997, in an effort to limit the spread of marine organisms through the ballast water of ships, the International Maritime Organisation (IMO) adopted ballast management guidelines providing for the exchange of ship ballast water out at sea (rather than in harbours). The guidelines further provided for regular removal of the ballast sediments from tanks, and for the decontamination treatment of ballast water and sediments prior to discharge. In 2004, the organisation went on to introduce a mandatory code of conduct for managing ship ballast. Enforcement difficulties notwithstanding, the new measures have helped to prevent the dispersal of invasive alien marine species via shipping – historically a particularly fecund pathway.

The task of intercepting invasive alien species imported in contravention of trade prohibitions, or which may be present in contaminated imports or personal luggage, is the responsibility of a country's conventional **exclusion mechanisms** – its border checks and surveillance systems, its customs inspections and its quarantine and decontamination treatment facilities. Yet these mechanisms are invariably under-staffed, under-resourced and poorly equipped, relative to the enormous volumes of incoming traffic and material they are expected to examine and process daily.

As tools for intercepting invasive species, such defences, then, in their present form, and with so many competing priorities (contraband, narcotics, explosives), are in most cases wholly inadequate. Expanding an already stretched exclusion apparatus to include the wherewithal to detect and intercept invasive alien species too amounts to a considerable added expense – in personnel and training, as well as in equipment upgrades and enlarged inspection, quarantine and treatment facilities.

The benefits of spending money on maintaining an effective exclusion apparatus capable of intercepting invasive species on high-risk entry pathways can be hard to justify to politicians and decision-makers. A model exclusion apparatus, set up and run at great expense, may over time prevent the influx of scores of invasive species. Each one of the excluded species might – had it been allowed in – have the potential, over future decades, to cause damage amounting annually to many times the total in operating costs ever incurred by the exclusion apparatus.

Yet, in the short term, what is there to show for the success of such an apparatus? There are absences only, miles of absences

– with not a single adversary to be seen. This great triumph, understandably, may be hard to convey to governments, which might want something rather more tangible to claim credit for than an event that has not occurred. International donors and development agencies, likewise hankering for tangible achievements to crow about, have the same problem. Efforts to prevent alien species' invasions, then, because their aim is one of maintaining long-term absences, rather than of brandishing conspicuous short-term accomplishments, have tended to be dogged by a lack of ready funding and budgetary support.

Awareness

Public awareness and understanding may also be lacking. Members of the public, made aware of the issue and engaged in the preventive effort, can make an enormous difference. Well-informed travellers are the front-line in any campaign to prevent the dispersal and spread of invasive alien species. A well-informed public is more likely, moreover, to appreciate the need for preventive checks and other regulations, which otherwise might come across as just an inconvenient nuisance. Access to information then, in the form of posters or notices displayed at entry points, or published alerts in travel magazines and other media, is another important aspect of effective exclusion strategy.

Sea transport, one of the frequent pathways for IAS introductions ©iStockimages

Inculcation of awareness at all levels of society – social, economic and political – is of course an essential first step towards mounting a successful campaign to prevent the influx and spread of invasive alien species. Alien invasions, though, are often the result of entrenched human values, habits and patterns of behaviour. So awareness alone may not be enough to bring about the *behavioural changes* that are required for such campaigns to be effective. We know, from humanity's response to the impacts of global climate change, how difficult it can be, even against a backdrop of almost universal awareness (of the need to reduce anthropogenic greenhouse gas emissions, say), to usher in behavioural adaptations that might help to mitigate these impacts.

Awareness regarding the invasive species' threat is, in the continuing absence of a global treaty (such as that of the Intergovernmental Panel on Climate Change), still far from universal. Yet, even in nations where awareness campaigns have succeeded in raising the profile of the invasive threat through the dissemination of information and educational materials, follow-up actions have not necessarily resulted. The focus now is on changing patterns of behaviour in relation to invasive species through what is known as 'social marketing'.

The aim of a **social marketing** campaign is to build motivations and partnerships through which awareness of a pressing social need might be translated into *concrete* actions which address that need. The Working for Water programme in South Africa (described in detail in the following chapter, *see pp. 77*) is a good example of how social considerations and benefits, built into a strategy for managing infestations of invasive alien plant species, can provide the catalyst for converting public awareness into effective practical interventions on the ground.

The success of the global HIV-Aids campaign is perhaps the most obvious recent example of how profound social and behavioural changes, engineered in the wake of a sustained global campaign of social marketing (including targeted communications and awareness

Awareness creation was an important component of the project through products and education), have been able to limit the spread of one especially devastating invasive alien species, in this case a virus.

Risk assessment

Another important aspect is that of determining the level of invasive risk associated with the introduction of any species which may be new to a country. For this, a sound regulatory framework is needed, representing and ruling on the wider interests – environmental and social, national and regional – of alien species' introductions that are proposed by agri-business or by commerce. Under such a framework, the introduction of species deemed to pose an unacceptable invasive threat to ecosystems and societies as a whole can be prohibited under international trade law, irrespective of how useful, or profitable, the species in question might be to a minority of would-be importers or investors.

A risk assessment is the standard procedure for determining whether or not the proposed introduction of an alien species can be authorised. Invasiveness cannot always be reliably predicted, however. Species that show no invasive tendencies in one region may prove invasive in another, and vice versa. It may also take many years for the invasiveness of an introduced species to become apparent. The most reliable indicator for invasiveness, then, is to be found in whether or not a species has become invasive elsewhere in its introduced range, particularly in ecosystems that are comparable and which boast similar climatic and geographic conditions.

Certain attributes among plants may create grounds for suspicion. Such attributes typically include:

- the ability to grow fast and reproduce readily (often asexually, by vegetative means, as well as sexually, via the ministrations of generalist pollinators)
- the ability, as hardy generalists, to tolerate a broad spectrum of environmental conditions and soil types, and to exploit a variety of nutrients
- adaptive mechanisms, such as the ability to fix atmospheric nitrogen, which may alter nutrient-recycling patterns
- the possession of deep-probing or extensive root systems, which may deplete available ground water and so lower water-tables, and
- production of abundant seeds, capable of utilising highly effective agencies of dispersal

Species whose foliage, outside their home environments, is poisonous to animals, or which are allelopathic (meaning they release chemical toxins into the soil that inhibit growth among plants of other species, or prevent the seeds of other plants from germinating), are usually also a high risk.

Plants belonging to certain taxonomic families, such as the Fabaceae (or legumes) and the Asteraceae (daisies), which are disproportionately well represented globally among invasive species, are best treated with particular caution.

All these are factors that have to be taken into account when carrying out a risk assessment. Fortunately, risk assessors now have access (as we shall see in the next chapter) to a very extensive literature on alien species' invasions and their history in different regions of the world. In being able to draw on documented case histories elsewhere, assessment teams are better equipped than ever before to make informed judgements on the likely impacts of introducing particular alien species. A repetition of mistakes of the kind made in the past may therefore be avoided. 'Exclusion lists' of prohibited species whose introduction is not permitted under any circumstances are now an established part of preventive strategy in many countries.

Much harder to evaluate are potentially invasive alien species that also offer clear economic benefits. A benefit–cost analysis taking into account both direct costs and indirect costs (in terms of disruption to ecosystem services, for example) may then have to be carried out as part of the risk assessment process. Where the trade-off between the value of the prospective benefits to a country or region and the likely associated impact costs can be justified, the introduction of such a 'conflict species' may be approved under strict conditions, subject to a satisfactory environmental impact assessment providing for responsible long-term containment and mitigation within the zone (or zones) proposed.

A decision authorising the introduction of a useful alien species that may also be invasive cannot be taken lightly, as such a decision, once taken, is irreversible. If the species does go on to become invasive, then future generations across society as a whole might be lumped with having to bear the impact costs. These costs can be very substantial – as we know only too well from the heavy price we are paying already, and can expect to have to go on paying, for invasions that have resulted from the ill-considered deliberate alien species' introductions of yesteryear.

Conservation measures

Sound conservation practices in nature reserves, national parks and other protected areas can serve as an important 'second line of defence' in helping to keep invasive alien species that have already infiltrated a country out of havens of biodiversity. Alien species' infestations, after all, are often a manifestation of ecological stress following disturbances to natural ecosystems. A pristine wilderness, made up entirely of native plant species that have co-evolved together over many thousands of years, is often stable and robust enough to resist colonisation by alien invaders. Sometimes, and on islands in particular, there may be vacant niches within an intact native plant community that invasive alien species can occupy. In most cases, however, it is areas of disturbed ground that provide the invaders with their points of entry.

Disturbed ground in a conservation area is usually the result of increased human traffic and of the expanded tourism infrastructure installed – in the shape of roads and hiking trails, lodges and campsites, walkways and viewing platforms, picnic sites and other facilities – in order to cater for this influx. Unfortunately, the longer-term implications, particularly with respect to creating conditions ripe for alien invasions, are frequently overlooked in the scramble for short-term profits from tourism.

Scars in the landscape may appear where roads and tracks have been constructed, or in the aftermath of road maintenance or the digging of roadside ditches. They may appear where tracts of indigenous habitat have been cleared to accommodate tourist amenities, or to create fire-breaks, or where pathways or trails have been cut through forests or through other previously intact stands of native vegetation. The scars may even be the result of over-grazing, or of soil-capping induced by repeated trampling or off-road driving. They may be the result of natural disturbances, caused by tree-falls for example, or forest fires. Whatever the cause, it is such disturbances that open up 'weak spots' in the defences of indigenous plant communities, giving the invasive aliens the narrow window of opportunity they need to gain a foothold from which to begin their advance.

The seeds of invasive plant species, carried in the radiators and on the wheels and under-carriages of vehicles, or on the soles of people's shoes, or which are dispersed by birds or animals, or by the elements, germinate readily on being deposited in such disturbed terrain. Some of the dispersed seeds come from invasive species that were thoughtlessly (often illegally) planted as garden ornamentals or as perimeter hedges in and around the compounds of park lodges and campsites. Sometimes it is graders and earth-moving machines brought in to maintain park roads and to dig ditches, or mowers and slashing implements used to trim roadside vegetation, which carry in and deposit the seeds. Usually, it is these machines and implements, along with the passing traffic of people and their motor vehicles, which help to scatter the seeds and spread the plants once they have gained a foothold.

Uganda's Bwindi Impenetrable Forest – a protected island in a sea of humanity ©Arne Witt

PATHWAYS OF INTRODUCTION

THE same few pathways and vectors are used by whole rafts of invasive alien species. So, exclusion efforts are best focused, not on intercepting individual species, but on interventions designed to block entire avenues of spread. Common pathways for the introduction of invasive alien species include:

INTENTIONAL INTRODUCTIONS

- Plants introduced for agricultural purposes
- Exotic plants introduced for forestry use
- Non-native plants introduced for use as soil improvers
- 'Aid trade'
- Ornamental or hedgerow plants
- Germplasm
- Mammals or birds released for hunting purposes
- Animals released on islands as sources of food
- Biological control agents
- Fishery releases
- Pets released, or escaping, into the wild
- Aquarium trade
- Releases intended to 'enrich' the native flora and fauna

INTRODUCTIONS VIA CAPTIVITY

- Escapes from botanical gardens, for example, or zoos
- Feral domestic animals
- Escapes from aquaculture or mariculture
- Escapes from research institutions or facilities

ACCIDENTAL INTRODUCTIONS

- Contaminants of agricultural produce
- Seed or invertebrate contaminants of nursery plants
- Seed or invertebrate contaminants of the cut flower trade
- Organisms in or on timber imports
- Seed contaminants
- Soil inhabiting species
- Contaminated imports of machinery, equipment, vehicles and military hardware
- 'Hitchhikers' in, or on, packaging materials
- 'Hitchhikers' in, or on, mail or cargo
- 'Hitchhikers' on aeroplanes
- Ballast water on ships
- Ballast soils
- Sediments in ballast water tanks
- Hull fouling on ships
- Debris
- Tourists and their clothing, footwear, luggage, or equipment
- Diseases in animals traded for agricultural or other purposes
- Parasites and pathogens of, or 'hitchhikers' on, aquaculture and mariculture

(Source: Wittenberg and Cock, 2001)

At first, the appearance of a new roadside invader may not be taken seriously. After all, the newcomer will usually be just one among many species of weeds seen to be occupying the niches afforded by such verges. Roadsides and ditches offer a particularly good point of entry for weeds, not only because they are scarred areas of the landscape, but also because they receive comparatively plentiful water, benefiting from the capture of rainwater run-off from the roads. Channels of flowing water in roadside ditches also help the plants to disperse their seeds.

In Africa, familiar roadside weeds – known as ruderals, for they appear on waste ground – may include Lantana, *Lantana camara*, Bug Weed, *Solanum mauritianum*, and various species in the genus *Senna*, such as the Peanut Butter Cassia and Stinking Weed. Other common ruderal weeds may include introduced *Sida* species (belonging to the Mallow or Hibiscus Family, Malvaceae); the Mexican Marigold, *Tagetes minuta*, and that well-known toxic species from the tropical Americas, the Thorn Apple, *Datura stramonium* (also known as the Devil's Trumpet).

Black Jacks, *Bidens pilosa*, and other yellow-flowering members of the Daisy Family (Asteraceae), including various species of *Conyza* and *Acanthospermum*, are notorious colonisers of disturbed soils. Some of these weeds are weak competitors, however, and are regarded as 'pioneer' species only, being limited to wasteland environments. Others, such as the Mexican Sunflower, *Tithonia diversifolia*, are more vigorous and may go on to spread more widely, out-competing and displacing native communities of grasses and herbs. Yet others – including the likes of *Parthenium hysterophorus* and *Chromolaena odorata* – have the potential, once established, to take over entire savannah ecosystems.

While the weeds may vary in species and composition, this is exactly the scenario that is being played out, over and over, in beleaguered conservation areas the world over. It may be difficult to intercept such alien invasions, given how the pathways and vectors responsible for introducing the invaders are mainly the very people and their vehicles on which the protected areas depend for their revenues. Yet there are a number of conservation management actions which can be taken in order to reduce the likelihood of invasions.

The growing, on the compounds of tourist lodges and campsites within protected areas, of ornamental species that are known to be invasive or potentially invasive can be contractually forbidden, for one thing. Many countries have laws (the Kenya Wildlife Act, for instance) that prohibit the introduction, anywhere within a protected area, of exotic (alien) species – of animals as well as plants. And yet in some of these countries, invasive exotic plant species are to be found in abundance, not only on the grounds of lodge concessions, but also in tended flowerbeds at the entrance gates and around the headquarters of the park authorities themselves, making a mockery of the legislation these authorities are supposed to be enforcing.

Invading plant species should be as much a focus of routine monitoring activities in national parks and reserves as poaching, trespassing and other more conventional surveillance priorities. The early detection of new invasions may prove decisive, if a rapid containment response follows, in forestalling potentially devastating full-blown invasions – of species that, left to their own devices, may ultimately be impossible to eradicate, and which may go on, year after year, to incur enormous control costs.

The mandatory steam-cleaning, prior to entry, of vehicles and machinery brought in for building, infrastructure repairs and road works can be made a stipulated pre-condition for contractors undertaking maintenance and civil engineering projects in protected areas. Strict enforcement of existing codes of conduct, governing off-road driving for example, or disembarking from vehicles in unauthorised zones may help to reduce levels of disturbance to the native ecology. More careful planning of new roadways, tracks and walking trails may also help limit the extent of environmental disturbance.

Fires in conservation areas often create conditions that enable colonising plants to gain a foothold. Fire-fighting crews and vehicles are, while battling wild forest fires, often facilitators of invasions, bringing in and dispersing the seeds of the invaders. In the United States, 'cleaning stations' are now an established part of fire-fighting drill in wilderness areas. Similar preventive measures, in parts of Africa where deliberate burning is used as a tool for managing old-growth grassland and for encouraging renewal among grasses in protected areas, may also be considered.

In some nations (New Zealand, for example, and Australia), the boots of visiting hikers from abroad are routinely put through (steam) cleaning stations at airports and at other entry points, to ensure that any seeds potentially embedded in mud clinging to the under-soles cannot be deposited in sensitive wilderness environments. Similar measures have been introduced on the Antarctic Peninsula, where already, in places where the ice-shelf has recently melted, invasive alien plant species brought in as seeds on the shoes or the clothing of unsuspecting research scientists and tourists are beginning to become established.

Preventive measures can never be entirely successful. People, wherever they go, will continue to carry other invasive species with them into new environments. Very little can be done, moreover, to prevent the influx of invasive plants whose seeds are dispersed by the elements (by cyclones, say, or by wind or water), or via the comings and goings of wild mammals or birds. A functioning preventive apparatus, capable of reducing the rate of alien invasions on pathways and through vectors that can be intercepted, is nevertheless an important component of any National Invasive Species Strategy and Action Plan.

Instruments – global, regional and national

How more tools than ever before are available to nations in the battle, globally, against the ravages of invasive alien plant species

The destructive impacts of invasive alien species – and of our own species, above all – are inescapably obvious. Yet we are doing very little to alleviate the rapacious and devastating repercussions of our human invasions. Unchecked population growth and sprawl, unrelenting habitat destruction and environmental degradation, unsustainable land and resource use, plunder of the world's oceans, displacement and extinction of other life-forms: all are manifestations of alien invasion on a scale unprecedented in the planet's long history. Indeed, the monopoly our own species has achieved is such that even the global climate is affected by human activities.

CHAPTER FOUR

The end result of our invasive onslaught, if this is allowed to continue unchecked, will be the exhaustion of the biological resources of Planet Earth – not to mention the collapse of our own species. We, though, alone among species, possess the faculty of reason. We can, if we dare look, see the writing on the wall. We may not like to think of ourselves as an invasive species, even though that, rationally, is what we are. And we are not alone either. Other alien invaders, hordes of them, all rival species that we have introduced, are getting in our way and threatening to undermine our exclusive dominance over and subjugation of productive environments around the world.

Calls for us to address our own direct invasive impacts on environments have so far gone largely unheeded. Our population continues to grow at an alarming rate; the destruction of forests and other natural habitats continues apace. Biodiversity suffers. Living conditions and livelihoods among vulnerable communities in poorer countries deteriorate. The litany of pressing environmental concerns on the global conservation and sustainable natural-resource-use agendas of organisations such as the Convention on Biological Diversity (CBD) continues to mount up.

Invasive species introduced by us are no longer just a threat to our food and water security and to the resource needs and well-being of our mushrooming populations; they have also invaded most of the world's conservation areas, and are threatening to overwhelm what natural biodiversity remains. This shocking realisation prompted calls during the 1980s for an urgent and well co-ordinated response – of actions at the global, regional, national and local levels – to prevent alien species' invasions and to restrict the further spread of existing infestations …

Global instruments

In 1992, the Convention on Biological Diversity (CBD), the international agreement ratified at that year's inaugural Earth Summit in Rio de Janeiro, Brazil, committed all signatory countries, under its Article 8(h), "… as far as possible and as appropriate, to prevent the introduction of," and "to control or eradicate those alien species which threaten ecosystems, habitats or species". Adopted by more than 150 governments (that number has since risen to 188), the CBD pact – obliging member nations to take wide-ranging steps to safeguard the biological resources of the planet – was passed into law in December 1993.

The CBD (www.biodiv.org) would go on to issue a set of *Guiding Principles for the prevention, introduction and mitigation of impacts of alien species that threaten ecosystems, habitats or species* to help member states implement Article 8(h). These were recommendations adopted during its sixth biennial meeting, held in 2002.

Earlier, following a landmark conference on Alien Species in 1996 in Trondheim, Norway, hosted jointly by the United Nations Environment Programme (UNEP) and the Government of Norway, the need for a global strategy addressing the problem of invasive alien species was identified as an urgent priority. It was further stressed that such a strategy should be so tailored as to elicit the practical involvement, not only of scientists, but also of representatives from all sectors in all nations, from governments and government ministries to resource managers and decision-makers in agriculture, commerce and industry, as well as educators and members of the legal profession.

So it was that, in 1997, a task force drawn from three international organisations – the Scientific Committee on Problems of the Environment (SCOPE), the Centre for Agricultural Biosciences International (CABI) and the International Union for the Conservation of Nature (IUCN) – embarked on developing a comprehensive strategy for tackling the problem of invasive alien species world-wide. With backing from the Global Environment Facility (GEF) and from UNEP, along with other organisations, this ground-breaking initiative culminated in the establishment, in 1998, of the Global Invasive Species Programme (GISP).

The new programme concentrated, to begin with, on gathering and disseminating information and on raising levels of awareness. This meant reviewing the status of all known alien invaders. It meant developing effective tools to assess and to quantify the respective impacts of invasive aliens on contrasting ecosystems, managed and natural, around the world. It meant devising sound predictive and early warning criteria and methods of risk assessment. It meant formulating clear best-practice guidelines for pre-empting potential invasions, responding to new invasions, and managing existing infestations. And finally, it meant collating and publicising all this information – on a website (www.gisp.org) and in publications and other media – in a simple, engaging way that would be accessible to all.

In providing a global forum for sharing problems and exchanging ideas, the GISP initiative accumulated a wealth of data on troublesome alien invasions. Extrapolating lessons from all these case histories, the programme was able to develop a wide range of prospective interventions and solutions. Its recommendations were instrumental, for the first time, in giving policy-makers and regulatory authorities around the world a much-needed core resource, offering useful, practical guidelines for confronting the menace of invasive alien species. The GISP guidelines went on to be disseminated, on-line and in published form, as *Invasive alien species: a toolkit of best prevention and management practices*.

At the same time, it became apparent that legislative frameworks governing the movement of species under many of the existing international trade agreements were inadequate, or vague, with respect to addressing the risk of spreading invasive aliens. Co-operative efforts aimed at rectifying such shortcomings and discrepancies, and at harmonising these agreements and bringing them more into line with CBD protocols, were to form another of the GISP initiative's priorities.

Provisions under most international trade agreements have always been directed primarily against spreading pathogens and pests that are known to cause diseases in humans, or damage to agriculture, forestry, or fisheries. A good example is the World Trade Organization's SPS Agreement (or Agreement on the Applications of Sanitary and Phytosanitary Measures, to give this its full name), which has been in effect since 1995, when the WTO succeeded the earlier General Agreement on Tariffs and Trade (or GATT). Another is the UN Food and Agriculture Organisation (FAO)-affiliated body, the International Plant Protection Convention (IPPC), amended most recently in 1997, which guards against the spread of pests in traded plants and plant products. (Significantly, invasive alien plant species are now included in the IPPC's definition of what constitutes a pest.)

Trade agreements, by their nature, are driven by economic considerations.

Some, like the SPS Agreement, have been criticised for overlooking what is known as the Precautionary Principle when evaluating the potential risks associated with trading in alien species. Endorsed by the CBD, this principle holds that *where an introduced species' possible impacts (not just on commercial interests, but on wider ecosystems and societies as well) have yet to be established scientifically, international trade in such a species should be treated as a potential invasive risk, until proven otherwise* – obliging all responsible would-be importers (and exporters) to exercise due caution; to play safe rather than plead sorry.

All too often, in cases where the damaging invasive impacts of introduced species become apparent only retrospectively, it is the recipient nations that are saddled with having to bear the costs and socio-environmental consequences of the damage (often over decades, if not forever), while the exporting nations, for their part, can exonerate themselves on the grounds of ignorance, their profits unscathed. We have not reached the point – yet – where affected nations may start seeking legal reparations for costly invasions foist upon them. But that day, surely, cannot be far off. As it is, the onus is still on recipient countries to make sure (regardless of the phytosanitary certificates submitted by exporters) that import consignments are not contaminated. This is just one of the many complex issues

Calliandra calothyrsus is becoming invasive in Uganda – inflorescence with wasp, near Masaka ©Geoffrey Howard arising from efforts at the global level to restrict the spread of invasive alien species.

The GISP initiative was discontinued in 2010, owing to funding difficulties. Yet the Global Strategy on Invasive Alien Species that it was instrumental in drawing up continues to provide the mainstay of ongoing efforts around the world to combat the spread of invasive alien species. The programme's website and the many authoritative publications and training manuals it produced – including several popular works, such as *Africa Invaded*, published in 2004 – remain valuable references. Another important resource generated under the programme, the Global Invasive Species Database (GISD), today managed by the IUCN's Invasive Species Specialist Group (ISSG) and posted on www.issg.org/database, provides free access to a wealth of information on invasive alien species.

CABI's Invasive Species Compendium (ISC), posted on www.cabi.org/isc/, offers yet another accessible mine of useful information on alien invaders.

The use of these resources will prove critical in responding to some of the Aichi Biodiversity Targets set in 2010, as part of the Strategic Plan for Biodiversity 2011–2020 unveiled at the tenth meeting, in Nagoya, Japan, of the Conference of the Parties to the CBD. Target Number 9, listed under Strategic Goal B (subtitled *Reduce direct pressures on biodiversity and promote sustainable use*), advocates that, "By 2020, invasive alien species and their pathways are identified and prioritized, that priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment."

Regional instruments

At the sub-global level – and in the developing world especially – many regional groupings have so far made only sporadic efforts to prevent the introduction of, or to limit, the spread of invasive alien species. Whereas most such bodies, on their statute books anyway, acknowledge the problem (and the part it is playing in


Gelada Baboons, endemic to the highlands of Ethiopia ©Arne Witt

impoverishing biodiversity, exacerbating poverty and hampering development), a combination of budgetary constraints, rival priorities, political distractions and general incapacity has meant that in practice very little remedial action is being taken.

The African Union's New Partnership for Africa's Development (NEPAD), in its Framework Action Plan for the Environment, for example, adopted in 2001, identifies invasive alien species as one of its core programme areas, conceding that such species are a "contributing cause of poverty and a primary cause of species' loss, ecosystem decline and, as such, a threat to sustainable development." Translating this expression of concern into concrete interventions on the ground has proved elusive, however.

To date, across much of sub-Saharan Africa, very little funding has been allocated to the setting up of even rudimentary measures to intercept the pathways of invasive alien species (through customs checks at borders, say, or surveillance at entry points, or by enforcing quarantine regulations) – despite the dramatic surge over recent years in intra-regional trade activity. What international funding there has been, in the form of donor support, has been channelled mainly into projects targeting high-profile alien invaders such as the Human Immunodeficiency Virus (HIV) and other pathogens that directly threaten human health. Donor-funded projects targeting invasive alien plant species, in particular, have been few and far between.

National instruments

At the national level, only one government in sub-Saharan Africa has a sustained and well-funded programme in place for dealing with invasive alien species. That country is of course South Africa, and its strategies and actions in countering the spread of alien invaders are today recognised as some of the most enlightened and successful in the world – as we shall see (below). By contrast, few other countries in sub-Saharan Africa have instituted systems for intercepting invasive species and for managing their spread – and none has got so far even as to draw up a National Invasive Species Strategy and Action Plan, let alone develop the capacity with which to act upon such a plan. The same is true of countries in Asia, some of which – like their counterparts in Africa – are also suffering disproportionately as a result.

The South African response is spear-headed by a novel government-run initiative called the Working for Water (WfW) Programme. Founded in 1995 and administered to begin with through the South Africa Department of Water Affairs and Forestry, the programme now falls under the Department of Water and Environmental Affairs. It has been instrumental to date in clearing alien plant infestations from more than one million hectares of invaded land at more than 300 sites, mostly in water catchments, in all nine of the country's provinces. At the same time, the programme has been able, each year, to create jobs for more than 20,000 people from previously disadvantaged communities. Having started out with a modest annual budget allocation of US$ 2.5 million (in poverty-relief funding), the WfW programme now has an annual operating budget in excess of US$ 160 million.

The programme has succeeded on many levels. Its message, first of all, in being directed at conserving water, is readily understood in a country where fresh water is naturally scarce, and where citizens are only too aware of the constraints imposed by water shortages. In South Africa, alien plant invaders are also visibly numerous and rife, particularly in water catchments. There had been well-publicised studies showing how water-guzzling woody alien plant species were consuming huge amounts of run-off from stream flows. So removing such plants seemed perfectly logical – to policy-makers and members of the public alike. In being able to build upon such an obvious and well-understood link between cause and effect, the WfW programme did not have to 'sell' complex cost–benefit arguments (still a major stumbling block for many developing countries) in order to justify invasive alien plant control.

South Africa is also wracked by stubbornly high levels of unemployment. So the programme's social component – that of helping to alleviate poverty by creating jobs for people in marginalised communities – has elicited further popular (and political) support for WfW projects. The community participation has attracted media interest, both nationally and abroad. The publicity has in turn helped to drum up awareness among the wider South African public. Such awareness (again, sorely lacking in most other parts of Africa) is critical in scaling up the battle against alien plant invaders.

An integrated cross-sector approach, meanwhile, involving different government departments (including those of Environment, Agriculture, Trade and Industry, Social Services, and Tourism), at both the national and the provincial levels, together with independent conservation bodies, environmental NGOs, social welfare organisations and private companies, has further contributed to the effectiveness of South Africa's response. All too often, planned interventions elsewhere in the developing world are undermined by the tendency among different ministerial sectors and interest groups within a country to pull in different directions.

In 2001, South Africa's Conservation of Agriculture Resources Act (CARA) was amended to incorporate strict regulations on invasive alien plants. Under the amended Act, no fewer than 198 of the 9,000-odd alien plant species that are known to have been introduced into the country were classified as invasive. The offending species were listed in three legal categories. Those in Category 1 (150 species) were not to be grown at all, and were to be eradicated. Species in Category 2, recognised as having commercial or utility value, could be grown only with a permit and under controlled circumstances in demarcated zones away from watercourses and floodplains; while those listed under Category 3 were species whose existing plants could stay (except at sites near watercourses and floodplains), but which could no longer be planted anew, propagated, imported, or traded. This legislation is in the process of being amended again – and expanded, to the extent that in 2013 restrictions may be broadened to apply to as many as 350 classified invasive plant species.

A clear legislative framework, coupled with the political will to go on providing budgetary support for vertically integrated action programmes extending to, involving and benefiting communities at the local level, has been central to sustaining the South African war on weeds. Heightened public awareness has benefited further from the publication, at the provincial level, of handbooks containing information on locally-occurring classified invasive plants, complete with practical advice on how members of the public might contribute to the national effort by managing such species.

In the process, many of South Africa's garden nurseries have stopped selling alien plant species altogether, opting instead to promote indigenous plants exclusively. The situation elsewhere in Africa, by contrast, is that many of the plants being offered for sale by garden nurseries are of species with known invasive proclivities. Worse still, decorative plant species grown on the compounds of tourist lodges and camps located within many of Africa's best-known conservation areas are very often invasive aliens of the worst possible kind (*Lantana camara* included).

In a country where invasive alien plants still occupy a land area of more than 10 million hectares, South Africa clearly still has its work cut out. The WfW programme has in recent years been criticised for failing to build on its early momentum. Studies showing how, in places, alien plant invaders are regaining the ascendancy have taken away some of the gloss of the programme's early successes. Such criticism, coming from within South Africa, may itself be construed as a healthy form of independent monitoring. The programme, while it may not be perfect,

ELEMENTS OF A GLOBAL STRATEGY

The **Global Strategy on Invasive Alien Species**, developed in 2001 by the Global Invasive Species Programme (GISP), espoused the following core principles:

- Invasive alien species are a serious and growing threat to biodiversity, food and water security, human and animal health, and economic development
- Consolidated management actions for preventing the spread of invasive alien species globally are an urgent priority
- Eradication of invasive alien species can be difficult and expensive, yet eradication is possible; rapid response, though, is crucial
- Containment, suppression and control of invasive alien species are important secondary management options; the benefits accruing from such interventions often far exceed the costs of the actions taken
- Concerted international and national actions are essential if the scale of the invasive alien species' threat is to be kept within manageable bounds

Source: McNeely, J.A., Mooney, H.A., Neville, L.E., Schei, P.J., and Waage, J.K. (2001): *A Global Strategy on Invasive Alien Species*; Global Invasive Species Programme.

Based on these core principles, the then-GISP Secretariat advocated Ten Strategic Responses for Addressing the Problem of Invasive Alien Species:

1. Build management capacity
2. Build research capacity
3. Promote the sharing of information
4. Develop economic policies and tools
5. Strengthen national, regional and international legal and institutional frameworks
6. Institute a system of environmental risk analysis
7. Build public awareness and public engagement
8. Prepare national management strategies and action plans
9. Build IAS considerations into global environmental and development initiatives
10. Forge international cooperation

Prosopis juliflora encroaching on a canal ©Arne Witt is nevertheless instructive in showing what it takes to mount a long-term campaign to keep the ravages of invasive alien plants at bay. There are of course many far bigger national campaigns. Across the United States, for example, annual budgets allocated to controlling the spread of invasive alien species now run to more than US$ 135 *billion*.

The South African Working for Water Programme is innovative in doubling as a social welfare initiative. On a continent where environment-related priorities are often swept aside through having to compete, for government attention and for limited funding, with a raft of pressing social demands, the WfW model has shown how the two need not be mutually exclusive. Such an approach may yet have to be replicated elsewhere in Africa, if effective invasive alien plant management is to be more widely practised.

In the absence of control programmes, invasive alien plant species are running riot in many of the countries of sub-Saharan Africa. The social impacts of such invasions on lives and livelihoods in rural communities can no longer be ignored. Entire local economies and ways of life are suffering. Farming communities are losing ground to alien plant infestations. Pastoralists decry diminishing livestock carrying capacities on invaded pastures. Fisheries too are suffering. And invaded watercourses are drying up. No longer just a nuisance, invasive alien plants are today the cause of mounting hardship in Africa, hampering the economic development of nations and frustrating social welfare and poverty-alleviation efforts.

Governments, not surprisingly, have started taking notice. But what can they do? And how far might they be willing to go? Where, they ask, might they begin to tackle such a problem? There are, of course, no easy answers – and no quick-fix solutions. And, on a continent where people are famously adept at finding uses for everything (invasive plant species included), there are differences of opinion too over whether, with respect to some alien invaders, any intervention is even warranted. These are the so-called 'conflict species' – invasive species, that is, which despite all the damage and suffering they are causing are seen to possess some useful attributes as well. Such obstacles and dilemmas have resulted in a worrying lack of responsive action on the ground.

This has meant that, despite impressive gains elsewhere, governments across sub-Saharan Africa have (along with their various international donors and aid agencies) made very little progress towards implementing the national contractual obligations spelled out under Article 8(h) of the CBD. Projects aimed at fostering compliance in Africa have included a GISP regional networking drive that in 2002 brought together all the countries making up the Southern African Development Community (SADC). This project, called *Prevention and Management of Invasive Alien Species: Forging Cooperation throughout Southern Africa*, culminated in a three-day workshop held in the Zambian capital, Lusaka.

At the workshop, delegations – from Botswana, Malawi, Mauritius, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe – presented (for the first time, in most cases) their country strategies for preventing the introduction of and for managing infestations of invasive alien species. The exchange of ideas helped to strengthen and to harmonise efforts across the region to combat alien invaders.

A very much larger project, funded by the GEF (which is also one of the financial mechanisms of the CBD), was carried out in four African nations – Ethiopia, Ghana, Uganda and Zambia – between 2005 and 2010. Implemented by UNEP, this project, called *Removing Barriers to Invasive Plant Management in Africa*, was executed by CAB International (CABI) in conjunction with national executing agencies from the four participating countries and with assistance from the IUCN. The five-year project has succeeded in further expanding levels of awareness, in strengthening policy towards invasive species in West, eastern and southern Africa, and in building the capacity of nations to develop, institute


Population numbers of birds such as Ibis and Storks are affected by invasive species, especially aquatic and semi-aquatic invasive plants ©Geoffrey Howard

and apply effective, practical and sustainable long-term strategies for managing and controlling invasive alien species, particularly plants.

Lessons learned over the course of the project have since been applied to similar endeavours elsewhere in sub-Saharan Africa, as part of an ongoing process of what is known as 'scaling up' the continent's response to the spread of alien plant invaders.

The *Removing Barriers* project is the exclusive focus of Part II of this book.

Landscapes, such as these, are threatened by invasive plants such as Prosopis and various cactus species ©Arne Witt

PART II: THE CHALLENGES FOR AFRICA

'Scaling up'

Genesis and planning of the *Removing Barriers to Invasive Plant Management in Africa* project

How, on a landmass the size of sub-Saharan Africa, where alien plant invaders of so many different species are running riot, might a single project go about galvanising an effective continent-wide response? That is the dilemma which, come the turn of the 21st Century, was preoccupying organisations in the vanguard of the global fight against the spread of invasive alien species.

The escalating scale of the many threats posed by invasive alien species in Africa was identified – at a Phase-One Synthesis Meeting of the Cape Town-based Global Invasive Species Programme (GISP) in 2000 – as a particularly urgent management priority. The governments of most sub-Saharan African countries were doing little to honour their contractual obligations under the Convention on Biological Diversity (CBD) to protect their respective stores of global biodiversity from the ravages of the continuing influx and spread of invasive alien plant species.

At the same time, little was being done to curb the destructive impacts of invasive species on agricultural production and livestock productivity. The consequences for food security, on a continent where the overwhelming majority of people (between 80% and 90% in most nations) depend for their survival on subsistence agriculture or pastoralism, were cause for particular concern. Rapidly increasing flows of intra-regional traffic and trade meant that pathways for the spread of invasive species were becoming more plentiful in Africa, increasing both the incidence and the risk of damaging invasions.

It became apparent, in consultations with government representatives from some of the affected African countries, that a number of constraints were preventing them from addressing the problem effectively. The constraints most often cited varied little from one country to another. All fell within four broad categories: a weak policy and institutional environment; a lack of awareness and of access to critical information; inadequate arrangements for prevention and control, and a general lack of capacity.

Yet some encouraging signs were also emerging, despite these constraints and the resulting worrying dearth of concrete actions on the ground. Delegations from Africa were participating in more and more international invasive species' forums. Some nations were well represented, for example, at the GISP Synthesis Meeting in 2000. A parallel project carried out jointly by the United Nations Environment Programme (UNEP) and the Global Environment Facility (GEF) between 1998 and 2002 on *Best Practices: Dissemination of Lessons Learned for Dealing with the Global Problem of Alien Species that Threaten Biological Diversity* went on to elicit numerous requests from Africa for follow-up information and advice on how to apply the recommended tools and strategies in their respective countries.

From the collaborative exchanges that followed, it became clear that a number of barriers and stumbling blocks (including all those identified above) would have to be overcome if these countries were going to be able to draw up and start implementing effective National Invasive Species Strategy and Action Plans.

The Kuala Lumpur Declaration, meanwhile, issued at the Seventh Meeting of the Conference of the Parties to the CBD in 2004, decried the alarming acceleration in the rate at which biodiversity in developing countries was declining as a direct result of unchecked alien species' invasions. The CBD declaration urged all global funding institutions and development agencies to give special priority to projects that would enable developing nations to address the escalating threats posed by invasive species.

The US$ 12 million UNEP/GEF project that would go on to be called *Removing Barriers to Invasive Plant Management in Africa* was, in large part, a direct response to this appeal.

The challenge, for both UNEP and the GEF, was to develop a project that, while focusing on overcoming the management barriers in those African nations which had formally requested assistance, would deliver practical solutions that might also go on to be replicated more broadly, across regions and in other African countries as well. The goal from the outset was to achieve a dramatic 'scaling up', in as many different parts of Africa as possible, of the battle to prevent the influx, and restrict the spread, of invasive alien species …

Four pilot countries are identified

Representatives from four African countries were in 2004 invited to participate in the project's early development and planning phases. In all four pilot nations – **Ethiopia**, **Ghana**, **Uganda** and **Zambia** – the ravages of alien invaders were recognised as posing a serious and mounting threat to biodiversity and economic development. All had already prioritised, in their respective Biodiversity Strategy and Action Plans and in other national plans relating to the environment or to sustainable development, the urgent need to address the invasive species' threat. All, moreover, had expressly requested expert assistance at regional and international invasive species' forums and meetings.

The widely separated locations of the four participating pilot nations presented an obvious 'scaling-up' advantage – both in terms of the range of different habitats and ecosystems reflected and in terms of the different regional economic groupings that would be represented. So, for example, the scope of the project could include some ecosystems in arid and semi-arid zones; some in natural forests; some in savannahs, and some along major rivers and in lakes and wetlands. Different forms of land and resource use could also be represented, ranging from protected conservation areas of global significance to farmlands, livestock pastures and fisheries.

Regional economic groupings represented would include the Intergovernmental Authority on Development (IGAD) in Eastern Africa, of which both Ethiopia and Uganda are members; the East African Community (or EAC, to which Uganda also belongs); the Economic Community of West African States (ECOWAS), of which Ghana is a member, and the Southern African Development Community (SADC), to which Zambia belongs. Each of the four participating countries, while possessing the necessary infrastructure to implement such a project, would be well-placed too as a sub-regional hub from which, in each case, the reach of the project might potentially be extended into a broader regional context.

A project of this magnitude would of course require a formidable management and organisational structure. The GEF, as the project's funding agency, and UNEP, as the agency responsible for implementing the project, duly enlisted – for the task of coordinating and of executing the project at the country level – the services of the Centre for Agricultural Biosciences International (CABI), while another of the GISP co-founding partners, in the shape of the International Union for the Conservation of Nature (IUCN), was drafted in as the project's executing support agency.

In each of the four participating African states, a National Executing Agency was appointed. The appointed institutions were: in Ethiopia, the Ethiopian Agricultural Research Organisation (now the Ethiopian Institute of Agricultural Research); in Ghana, the Council for Scientific and Industrial Research; in Uganda, the National Agricultural Research Organisation, and in Zambia, the Environmental Council of Zambia (now the Zambian Environmental Management Agency).

Preliminary surveys carried out in 2004–2005, during the development phases of the project, set out to identify and define priorities in each of the four pilot countries. It was important, for example, to establish which of the many invasive plant species in each of the four nations should be targeted. Representative pilot sites would then have to be selected as areas of focus within each of the countries. Particular barriers to invasive plant management within each country, and at each prospective site, had to be identified and assessed. Linkages with existing initiatives in the host countries and with organisations engaging in complementary activities needed to be explored. Stakeholders at all levels of society, and in each of the prospective areas of focus in particular, had to be consulted and engaged.

Not until the preliminary surveys had been completed and their findings analysed, could a detailed plan of action, with clear operational components and strategies, be devised, adopted and pursued …

Ethiopia's Awash National Park, one of the project pilot sites ©Arne Witt

Eight plant invaders are singled out

Project teams in each of the four countries duly gathered information from across a wide range of infested habitats, natural and managed, on the status and the impacts of dozens of menacing invasive plant species. The findings of these preliminary country surveys were then evaluated by the International Project Coordination Unit, hosted by the CABI Africa Regional Centre in Nairobi, Kenya, in liaison with the project's other partner organisations.

Not surprisingly, it turned out that some of the documented invasive species were creating havoc in more than one of the participating countries. The Water Hyacinth, *Eichhornia crassipes*, for example, was identified as a serious problem for the lakes, rivers and wetland environments of all four countries. Some of the species were well-known and long-established invaders, such as the widespread prickly-stemmed shrub *Lantana camara* from Central and South America. Some were comparatively recent invaders, such as *Parthenium hysterophorus*, rife already in one country (Ethiopia), but emerging as a potentially devastating threat for neighbouring African countries too. Some were 'conflict species' – invasive species, that is, like *Prosopis juliflora*, which despite all the damage their infestations were causing in colonised habitats in Ethiopia and elsewhere were looked upon as having some useful qualities as well.

Other menacing plant invaders highlighted in the project's pilot surveys included species – like the prickly shrub *Mimosa pigra*, also from Central and South America – which although naturalised for decades in some African countries (notably Zambia) were now posing a serious threat to the biodiversity of ecosystems (floodplains and wetlands, in the case of Mimosa) there and elsewhere on the continent. The Paper Mulberry, *Broussonetia papyrifera*, a deciduous tree of Far East Asian origin, now a serious problem for Ghana in particular, was another of the highlighted invaders in this category. Other species, such as the Spectacular Cassia, *Senna spectabilis*, a fast-growing deciduous tree from the tropical Americas, were identified as serious threats to protected forests in just one of the participating

Paper Mulberry (*Broussonetia papyrifera*) infestation in Ghana
©'Digi' Kweku Johnson

nations (Uganda, in the case of the Cassia). The lemongrass False Citronella, *Cymbopogon nardus*, was another species identified as posing a serious invasive threat (both to the biodiversity of habitats in conservation areas and to pastoralist savannah ecosystems) in Uganda only.

These eight invasive species, of the dozens that were collectively put forward for consideration in the preliminary country surveys, were selected as the priority targets for the *Removing Barriers to Invasive Plant Management in Africa* project. The eight species represented a good cross-section of different threats to different ecosystems, wild and inhabited. The contrasting geographical ranges of the respective infestations would at the same time present the broadest possible scope for a 'scaling up' of both preventive and management invasive species' interventions throughout Africa.

One of the targeted invaders (Prosopis) was a particular threat to ecosystems and livelihoods in arid and semi-arid regions of Africa. Two (Water Hyacinth and Giant Sensitive Plant) were a threat, in both protected and settled areas, to the continent's lakes, rivers, wetlands and floodplains. Two (Lantana and Parthenium) were threatening all terrestrial ecosystems, from farmlands and grazing pastures to riparian habitats in settled areas and in national parks and reserves alike. Two species (Paper Mulberry and Spectacular Cassia) were a threat to biodiversity in protected natural forests of global conservation significance. One (False Citronella) was undermining pastoralist livelihoods and economies on savannahs, while also threatening protected wildlife habitats …

Nine project sites are selected

Selection, within each of the four participating nations, of suitable project sites went hand-in-hand with the targeting of the individual invasive species. The International Project Coordination Unit based at the CABI Regional Centre in Nairobi had to decide, in consultation with the National Executing Agencies in each of the host countries, which – out of many potential sites – would best encapsulate and facilitate the project's broader national and trans-national objectives for 'scaling up' and at the same time meet the CBD's guidelines with regard to benefits to biodiversity.

In **Ethiopia**, three project sites were selected. At one site, the focus would be on Prosopis; at another, on the Water Hyacinth, and at a third on Parthenium Weed.

The **Amibara District** in the Middle Awash Basin of the country's Afar Region was chosen as the project site

Pilot sites in Ethiopia. Cities/Towns Pilot sites for the management of *Prosopis juliflora* – the thorny evergreen shrub from the Americas, also known as Mesquite, which was introduced deliberately into this and many other parts of Ethiopia in the 1980s, having also been introduced into arid and semi-arid zones of neighbouring Kenya. In most of these areas, its introduction was intended to help curb encroaching desertification and to provide shade, windbreaks and fuel wood for people. Its seed-pods, meanwhile, were promoted as offering a valuable supplementary source of livestock fodder.

Prosopis was introduced into the Amibara District in 1988. Since then, as in other parts of eastern Africa, the species – instead of developing into useful small trees – had formed impenetrable, shrubby thickets, which had spread rapidly and taken over pasture rangelands, invading river valleys and watercourses, lowering the water-table and displacing native savannah trees and grasses. The Prosopis thickets had invaded floodplains previously used for growing the traditional grain staples *tef* (*Eragrostis tef*, an indigenous love-grass species from which the Ethiopian bread *injera* is made) and sorghum. Cotton, citrus fruits, groundnuts and other crops grown on large-scale farms in the area, both state-owned and private, were all reliant on irrigation from the nearby Awash River, whose catchments were now also under threat.

Prosopis was threatening, moreover, to invade the Acacia savannahs of the 827-km² Awash National Park, just 40 km from the Amibara pilot site. The national park is home to the threatened Swayne's Hartebeest, *Alcelaphus buselaphus swaynei*, and has a bird list running to more than 460 species, some of them Ethiopian endemics.

At the Amibara site, then, the *Removing Barriers to Invasive Plant Management in Africa* project would be able, in relation to Prosopis, to address multiple impacts and threats. It would address the concerns of pastoralists and the forage needs of their cattle, camels, goats and sheep; the concerns of subsistence farmers, and the concerns of irrigation-reliant large-scale agriculture, public and commercial, while at the same time addressing the threat to local water catchments and the plight of a conservation area threatened with imminent invasion.

The nearby **Awash River Catchment System** provided locations for a second project site in Ethiopia. Here, infestations of Water Hyacinth, *Eichhornia crassipes*, had become a serious problem. The hyacinth invasion is thought to have begun after ornamental plants brought in by foreigners running fruit and vegetable farms in the highlands near Addis Ababa entered Melka Denbi, a small lake that in the wet season feeds into the Awash River. The hyacinth had then spread to the Aba-Samuel Dam – a wetland of global importance for migratory birds – and to other water bodies in the Awash's upper catchment area, before going on to invade the entire river system. In the process, a string of connected lakes, notably Lake Koka and Melka Berbere, had also become infested.

Thick floating mats of the hyacinth had covered some entire water bodies (Melka Denbi included), fouling the water and impeding access by people and their livestock animals. In Lake Koka, the hyacinth infestation was threatening the function of an economically important hydro plant, and was clogging up the network of reservoirs and irrigation canals used by local sugar producers and other agro-industries. The Lake Koka infestation had been aggravated by the effects of eutrophication, caused by fertiliser run-off and by pollutants that were being swept into the lake from nearby factories. Again, at the various locations covered by this site, the *Removing Barriers to Invasive Plant Management in Africa* project would be able to address a broad range of different stakeholder interests and concerns.

The project's third selected site in Ethiopia was at **Welenchiti**, in the country's Oromia Region, about 40 km west of the Awash National Park. At this site, the focus would be on Parthenium Weed, *Parthenium hysterophorus* – a particularly menacing invader from sub-tropical areas of North and South America which is thought to


Parthenium infestations have driven pastoralists off their land – an Acacia woodland in Ethiopia ©Arne Witt

have been introduced accidentally as a seed-contaminant in famine-relief supplies brought into the country in the early 1980s. The main road between Addis Ababa and Dire Dawa in the east passes through the Welenchiti area, and is the pathway along which Parthenium Weed was first able to spread. This noxious annual weed had since taken over hundreds of thousands of hectares of farmland and grazing pasture in Ethiopia. It was spreading too in neighbouring Kenya, with the same disastrous ecological and economic consequences.

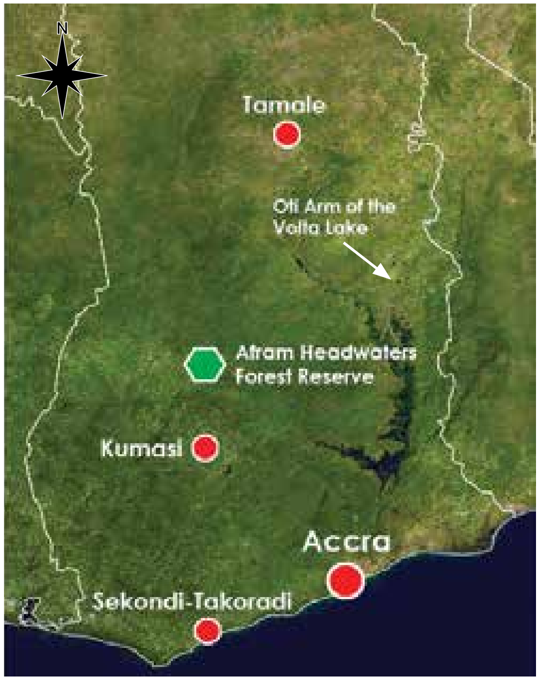
In the Welenchiti area, Parthenium's impact on crop yields, mainly of sorghum, tef and finger millet, had been so severe that even its local name, translated, means 'No Crop'. Yield declines of 40% were common, although in some un-weeded fields declines of as much as 90% had been recorded. Parthenium's impact on available forage in the Welenchiti area had been no less devastating. Being toxic to livestock, Parthenium had been responsible for similarly steep declines in the livestock carrying capacities of once-productive grassland habitats. Parthenium Weed's allergens were affecting human health too, causing ailments such as dermatitis, asthma, hay-fever, breathing difficulties and irritations of the eyes.

Along with Prosopis, Parthenium had become a serious threat to biodiversity in the nearby Awash National Park. Incursions into the park of domestic livestock herds were becoming more frequent, as forage outside the park diminished, under pressure from both Prosopis and Parthenium. Not only were the livestock animals likely to act as vectors in introducing the seeds of both plant invaders; the resulting over-grazing might also facilitate the invasion process, creating a spiralling cycle of degradation and decline, while threatening the survival of the park's 76 known mammal species. This scenario was being played out already in other parts of eastern Africa, where several national parks and reserves in both Kenya and Uganda were in the process of being invaded by one or other, or by both, of these aggressive colonising species.

For neighbouring countries, then, lessons gained from the Ethiopian interventions of the *Removing Barriers to Invasive Plant Management in Africa* project might have enormous potential spin-off benefits.

In **Ghana**, meanwhile, two project sites were selected. The focus at one of these sites would be on infestations of the Paper Mulberry, *Broussonetia papyrifera*, while at the other site the Water Hyacinth would again be targeted.

The **Afram Headwaters Forest Reserve**, 60 km north of Kumasi in the Ashanti Region of central Ghana, is an isolated 20,124-hectare eastern remnant of a once-vast semi-deciduous dry forest belt known



Pilot sites in Ghana. Cities/Towns Pilot sites

as the Upper Guinea Forest Block. The reserve had been created to protect an important watershed, as well as for timber extraction. Decades of selective logging and other intrusive human activities, including selective re-planting and sporadic cultivation, had radically altered the make-up of this forest, which nevertheless has remained one of Ghana's most important havens of natural biodiversity.

In 1969, a site adjacent to the forest was used as a trial plot for growing seedlings of the Paper Mulberry. The seedlings had been imported from the Far East, at a time when the then-Government of Ghana wanted to establish a domestic paper and pulp industry. In the Far East, the bark of these trees, which are native to NE Asia, had for centuries been used for making paper. The Ghanaian experiment was abandoned in the early 1970s. The trees, though, which may reach heights of up to 12 metres when mature, had flourished in their new environment and had proceeded to spread around the edges of the forest reserve.

A succession of forest fires during the drought-prone 1980s opened up gaps in the forest canopy, allowing the mulberry seeds, which are dispersed by fruit-eating birds and bats, to germinate in the burned clearings. The species had since spread deep into the forest. It had also proliferated along roadsides, colonising surrounding farmlands and pastures. The Paper Mulberry has an extensive lateral root system that re-sprouts vigorously after fires, while soaking up huge quantities of water. Infestations of these water-guzzling trees had resulted in declining crop yields, and had also reduced the productivity of livestock rangelands.

In Africa, the Paper Mulberry's invasive range was no longer confined to Ghana alone. In Uganda too, the species had become established in some areas (including the Budongo Forest Reserve, in the west of that country, near Lake Albert, and the Mabira Central Forest Reserve, north of Lake Victoria, between Kampala and Jinja), where it was starting to spread rapidly. So the choice of Ghana's Afram Headwaters Reserve as one of the pilot sites for the UNEP/GEF *Removing Barriers to Invasive Plant Management in Africa* project would hold some potentially valuable lessons for prevention and containment initiatives on other parts of the continent as well.

The **Volta Lake's Oti Arm** would be the project's other pilot site in Ghana. The 8,482-km² Volta Lake is one of the world's largest artificially created lakes, having come into being in 1965, following the construction of the Akosombo Dam in the Volta River Basin. The two 'arms' of the lake extend upstream along the converging feeder tributaries of the Afram and the Oti Rivers. The lake is of immense economic importance to Ghana, both as a fishing-ground and for the irrigation of farmlands on the Accra Plains. It is also a major transportation artery. The Akosombo Dam, for its part, generates sufficient hydro energy to power most of Ghana's electricity needs.

Despite its artificial character, Volta Lake is of significant biodiversity value. It supports fish of more than 150 species. Interestingly, it is also one of the few places where crocodiles of all three species that occur in Africa can be found – the Slender-snouted and Dwarf Crocodiles, that is, as well as the widespread Nile Crocodile.

Late in 1998, the presence of the invasive Water Hyacinth had been noticed in the upper northern reaches of the lake's Oti Arm. A rapid containment response, using both manual and chemical control methods, was marshalled in 1999, with the aim of stopping the hyacinth from entering the main body of the lake, where the ecological and economic consequences of a full-blown hyacinth invasion would be disastrous. Yet, despite these efforts, the infestation had continued to expand, so much so that, by 2001, the hyacinth had spread over an area of more than 10,000 hectares, down a 100-km stretch of the Oti Arm – and was perilously close to entering the lake proper. Biological control measures were then taken, using the *Neochetina* Weevil species that had been successfully deployed in Lake Victoria and elsewhere. The infestation had been contained, but invasion of the entire Volta Lake was still a worrying threat.

The *Removing Barriers to Invasive Plant Management in Africa* project would, in collaboration with affected Oti communities, explore ways of bolstering the existing hyacinth containment effort in this part of Ghana. The aim would be to mitigate the hyacinth's impacts on biodiversity and livelihoods along the lake's Oti Arm, while at the same time averting the risk of spread – and of damage to the broader ecology of Volta Lake and to the function of the important Akosombo Dam hydro plant.

In **Uganda**, two pilot sites were selected. At one of these sites the project would focus on the management of a forest ecosystem affected by the Spectacular Cassia, *Senna spectabilis*, while at the other the focus would be on managing infestations of the lemongrass False Citronella, *Cymbopogon nardus*.

The 793-km² **Budongo Forest Reserve**, near Lake Albert in western Uganda's Masindi District, is famous, not just as the largest remaining expanse of natural forest on the eastern rim of the Albertine (or Western) Rift Valley, but also as a refuge for Africa's easternmost wild population of the endangered Common Chimpanzee, *Pan troglodytes*. The forest is unique in supporting an overlapping mix of flora and fauna from two normally disjunctive biomes – the Guinea–Congo Forests Biome of West and Central Africa and the Afro-tropical Highlands Biome of eastern Africa. Some of the bird species in this forest (the Yellow-footed Flycatcher, *Muscicapa sethsmithi*, for example) are known from no other locality in East Africa. The Budongo Forest Reserve, then, is a biodiversity hotspot of global conservation significance.

Over the past 60 years, however, the composition of the forest's vegetation had been altered through selective logging and through silviculture (which has favoured re-plantings of some valuable hardwood timber species at the expense of other trees). The challenge, now, was to balance the conservation of Budongo's biodiversity and ecological integrity with the sustainable production of hardwood timber and with the needs of local communities in the heavily settled adjacent farming areas. Part of this challenge would be to manage the destructive impacts of invasive plant species that had become established in the Budongo Reserve.

Pilot sites in Uganda. Cities/Towns Pilot sites

Monotypic stands of one arboreal invader in particular had already colonised large areas of the forest. The Spectacular Cassia, *Senna spectabilis*, a fast-growing deciduous tree from the tropical Americas, now occupied more than 1,000 hectares of the reserve and its surroundings, having out-competed and replaced native forest trees, along logging trails and in disturbed zones especially. The species had been introduced into many new environments around the world as a garden ornamental on account of its showy yellow flowers. At Budongo, rows of the trees had been planted as boundary markers around the forest's edge, in the 'buffer zone' between the forest reserve and neighbouring farmlands. The trees had also been planted in adjacent farmlands – for shade and as a source of firewood.

Spectacular cassia (*Senna spectabilis*), a South American tree, is rapidly invading forests in Uganda ©Geoffrey Howard

Once established, the Spectacular Cassia is difficult to eliminate, for it re-sprouts vigorously on being cut down. It is an extremely thirsty species, having an extensive root system capable of absorbing moisture and nutrients from deep-soil horizons. Its abundant seeds, produced in long cylindrical pods that are readily dispersed by the elements, may remain viable in the soil for as long as three years. The foliage of the trees is unpalatable to native wild mammals and livestock animals.

In collaboration with foresters and community groups, the *Removing Barriers to Invasive Plant Management in Africa* project would carry out management trials at Budongo, aimed at suppressing the Senna infestations and at restoring the ecosystem health of native forest and forest-edge environments and plant communities.

The **Lake Mburo National Park and environs**, in the Mbarara District of Southwest Uganda, would be the project's other Ugandan site. The 260-km² park encompasses a variety of habitats, ranging from Acacia woodland and savannah to aquatic habitats, including five small lakes (of which Mburo is the largest) and extensive marsh areas, fringed with papyrus. As a designated Important Bird Area, the park is home to birds of several species which (in the case of the range-restricted Red-faced Barbet, *Lybius rubrifacies*, for example) are rarely encountered elsewhere. The park is also the only remaining haunt in Uganda of the Impala antelope, *Aepyceros malampus*, formerly widespread in the country. The park's wild fauna had declined markedly over recent decades, as intensifying human population pressure had led to higher poaching off-takes and to more regular incursions by groups of people and their livestock herds.

Infestations of an invasive species of lemongrass, *Cymbopogon nardus*, or False Citronella, had been both a contributing cause and a consequence of the intensifying human pressure on the natural biodiversity of the Lake Mburo National Park.

The lemongrass is said to have been introduced into the neighbouring Kiruhura District of South West Uganda from the Indian sub-continent (although the species does also have African biotypes).

Mimosa pigra invading the Kafue River floodplain, Zambia ©Arne Witt

This coarse grass, which forms tussocks up to a metre-and-a-half tall, readily colonises bare, over-grazed soils. Regenerating rapidly after fires, it soon out-competes and replaces other grasses. The older leaves, while not toxic, are shunned by most grazing herbivores, even when no other forage is available. In parts of Southwest Uganda, once home to vast pastures of diverse wild grass communities replete with highly nutritious forage species, False Citronella now accounts for as much as two-thirds of the overall grass cover.

The consequences for pastoralism, by far the most important land use in this part of Uganda, had been nothing short of catastrophic. The area, after all, falls within the 'corridor' heartland of the famous Ankole breed of cattle. Descended from ancient African-domesticated Sanga cattle, these extraordinary beasts – renowned for their seemingly disproportionately long, yet always shapely horns, which in some cases, tip-to-tip, may span more than two metres – are the mainstay of the local economy. In some lemongrass-infested areas, cattle numbers had reportedly declined by more than 40%. The average milk yield per cow had dropped by more than 50%. The market value of malnourished animals sold to local butchers had fallen by more than one-third. Family incomes had plummeted accordingly.

By the 1980s, the invading lemongrass had taken over many of the traditional Ankole grazing pastures. Frequent dry-season incursions into the savannahs of the Lake Mburo National Park were the inevitable result, as the despairing pastoralists sought new grazing grounds. Inevitably too, the livestock herds had further dispersed the lemongrass, which propagates, not via stolon runners, but by the abundant self-sowing seeds it produces. Over-grazing and degradation within the park, meanwhile, had created the disturbed conditions that have enabled the False Citronella to spread. A spiralling cycle of environmental degradation and decline had ensued.

The *Removing Barriers to Invasive Plant Management in Africa* project would, in and around the Mburo site, seek to break this destructive cycle through developing an integrated management response to the problem. At the same time, the project would introduce preventive and early warning and detection systems through which to pre-empt a possible Water Hyacinth invasion of Lake Mburo and other lakes and wetlands in the park. The hyacinth had already infested nearby water bodies, and – as some of the invaded aquatic environments were linked to the Mburo Lake System via the Ruizi River – the threat of a seemingly imminent Water Hyacinth invasion had become yet another worrying concern.

In **Zambia**, two project sites were selected. The focus, at one site, would be on managing the destructive spread of the Giant Sensitive Plant, *Mimosa pigra*. At the other site, the focus would be on managing infestations of that most widespread of all terrestrial plant invaders, *Lantana camara*.

The **Chunga Lagoon** in the **Lochinvar National Park**, on the Kafue Flats south west of Lusaka in Zambia's Southern Province, was the site chosen for the management of *Mimosa pigra*. The Kafue River, part of the Zambezi drainage system, runs along the northern boundary of the Lochinvar Park. Extensive areas within the park, including the Chunga Lagoon marshlands, are seasonally inundated. This protected expanse of the Kafue Floodplain is a Ramsar Site harbouring biodiversity of global conservation significance. The area is home to the endemic Kafue Lechwe, *Kobus leche kafuensis*, a vulnerable antelope subspecies. It has long been an important refuge and breeding-ground too for the endangered Wattled Crane, *Grus carunculatus*.

By the early 1980s, *Mimosa pigra* – a prickly shrub of tropical American origin (a species which, by then, had been naturalised in Zambia for more than 60 years) – had spread from the Kafue riverbanks and was colonising the floodplain around the Chunga Lagoon and along the associated Nampongwe Stream. The rate of spread was gradual at first, but has accelerated dramatically over the past 15 years. Mono-specific stands of the species now cover more than 3,000 hectares of the floodplain, extending as well – increasingly – to areas outside the Lochinvar National Park that have traditionally provided essential dry-season grazing pasture for livestock.

The appeal of the Lochinvar National Park as a destination of choice for tourists has suffered immeasurably. Much of the wildlife for which the park is renowned has been driven out of the area. Unsightly

Pilot sites in Zambia. Cities/Towns Pilot sites sprawling thickets of *Mimosa pigra*, all of four metres tall in places, have in any case blocked out views of the river and are choking the Chunga Lagoon. Similar invasions are under way elsewhere in Africa – in central Mozambique's Gorongosa National Park, for example, as well as on floodplains and in seasonal wetlands in Malawi, Ethiopia, Ghana and Uganda, among other affected countries. The reason for *Mimosa pigra*'s sudden 'awakening' and rapid proliferation in Africa is far from clear, although hydrological changes induced (in part at least) by climate change are thought to be a contributing factor.

The challenge here, for the *Removing Barriers to Invasive Plant Management in Africa* project, would be to come up with an integrated management strategy through which to limit the spread and the impacts of *Mimosa pigra*, while devising an action plan for rehabilitating the floodplain ecosystem of the Chunga Lagoon area.

The **Mosi-oa-Tunya National Park and environs** would provide the project's other pilot site in Zambia. Mosi-oa-Tunya (meaning 'the Smoke which Thunders') is the local name for the Victoria Falls on the Zambezi River – one of the most famous of all Africa's natural wonders. The falls tumble more than 100 metres from a rim, itself more than 1.5 km wide, straddling the international border between Zambia and Zimbabwe. The spectacular falls and the unique 'mist forest' their cascading spray supports on both the Zambian and the Zimbabwean flanks of the river were in 1989 declared a World Heritage Site.

The 3,900-hectare Mosi-oa-Tunya National Park, in the Livingstone District of Zambia's Southern Province, although altered in some respects by human traffic and tourism, has remained a sanctuary of global importance for biodiversity, harbouring a distinctive flora (including several endemic plant species) and a range of aquatic and semi-aquatic invertebrates that occur nowhere else. The gorge below the falls is also one of only a few known nesting sites of the rare Taita Falcon, *Falco fasciinucha*.

Unfortunately, the noxious shrub *Lantana camara* has invaded all of the park's major habitats, including the unique mist forest below the falls. Even those pockets of fringing forest on the steepest-rising flanks of the gorge have been invaded. Native to Central and South America, Lantana – widely introduced into new environments around the world during the early part of the 20th Century as a garden ornamental and hedgerow plant – is today the most widespread of all terrestrial invasive plant species. It has become a scourge in more than 60 countries, including all the nations of sub-Saharan Africa. Having taken over vast expanses of the continent's farmlands and livestock pastures, Lantana infestations have proved more costly to Africa than have infestations of any other invasive alien plant species.

Thickets of Lantana, once established, are virtually impossible to eradicate. With the help of toxic chemicals the plants release into the soil, which prevent germination and inhibit growth among plants of other species, the invading Lantana thickets are able to smother and replace the native vegetation of the environments they colonise. In most invaded areas, Lantana flowers profusely year-round. Its sweet floral nectar attracts butterflies, moths (hawkmoths especially) and many other pollinating insects and birds, notably sunbirds. It produces abundant fruits – clusters of tiny berries that turn purple and then black on ripening. The ripe fruits are edible, and fruit-eating birds of many species (in Africa mainly mousebirds and bulbuls) flock in to feast on them. These birds go on to disperse the seeds in their droppings.

Lantana regenerates quickly after fires and coppices readily on being cut down. Burning or clearing its infestations just encourages its spread. Its foliage, being toxic, is avoided by most browsing mammals. Lantana is also extremely moisture-hungry. Grasses and other plants cannot grow in its shadow, so the soil's capacity to absorb and retain rainwater is lowered. Unimpeded run-off in the wet season may increase erosion on the slopes of Lantana-infested valleys. The impenetrable prickly thickets, massed along riverbanks, deny animals and

Mosi-oa-Tunya (Victoria Falls), Zambia ©Arne Witt people access to the water. Unsightly and obstructive thickets of Lantana, all of two metres tall, hamper wildlife-viewing, and cause wilderness areas to lose their appeal. Tourism suffers as a result.

In the Mosi-oa-Tunya area, the *Removing Barriers to Invasive Plant Management in Africa* project would seek, with the help of conservation authorities and tourism establishments on both the Zambian and Zimbabwean sides of the falls, to develop an effective management strategy for integrated control of *Lantana camara*.

At the same time, on the Zambian side of falls, the project would be seeking ways of eliminating infestations of Water Hyacinth from the Maramba River, a tributary of the Zambezi that flows through the town of Livingstone. Water Hyacinth infestations in Livingstone's sewage treatment ponds, especially, would be investigated, as these ponds are a known hyacinth reservoir from which the plants were escaping into the Maramba River and thence into the Zambezi. The hyacinth, was having a negative impact on tourism activities on the Maramba River, and affecting hydro-electricity generation at the Falls.

Linkages are established

Networking was another important aspect of the project's development and planning phases. Several of the environmental and development initiatives and programmes already under way in the four host countries and across their wider regions offered enormous scope for collaboration. Most were donor-funded initiatives focusing, not on invasive plant species particularly, but on aspects of biodiversity conservation and sustainable development more generally.

Many of the African communities being served by these initiatives would go on to benefit from incorporation, in consultation with the *Removing Barriers to Invasive Plant Management in Africa* project, of a component dealing with the management of invasive plant species. Through these complementary programmes, the project was able, for its part, to achieve a further scaling-up of the battle to combat the spread of invasive plant species on the continent. In the process, the project benefited too from insights (into the impacts, on women for example and other vulnerable social groups, of invasive plant species) that were forthcoming from the work of NGOs and other agencies with perspectives based primarily on poverty alleviation, for example.

In Africa, infestations of invasive plant species have a disproportionate impact on vulnerable social groups. In rural areas, women are the principal food providers. It is they who plant the crops and tend the fields; who harvest, store and prepare the food, and who set up and find markets for surpluses, creating livelihoods and keeping rural families and communities fed. In the process, it is estimated that hand-weeding alone may take up more than 20 billion hours each year of the time of 100 million women across Africa. In some countries, such as Uganda, women may spend as many as 120 days each year engaged in weeding.

The spread of invasive alien plants in croplands is making this task increasingly onerous, while at the same time resulting in reduced crop yields. This places further stress on the ability of the women – over and above the many other crucial social roles they perform – to maintain the food security of their communities. The effects of alien plant invasions on the lives of women in vulnerable rural communities would therefore provide an important area of focus for the *Removing Barriers to Invasive Plant Management in Africa* project.

In all, the project was able to forge close working relationships with NGOs and development agencies responsible for operating more than 30 different programmes in Africa. In Ethiopia for example, the networking process significantly enhanced the Prosopis Management component of FARM–Africa's *Afar Pastoralist Development and Emergency Project*, aimed at achieving more sustainable use of pastoralist lands in Afar Regional State. Cooperation with CARE Ethiopia, meanwhile, on its *Awash Conservation and Development Project*, saw the management of both Parthenium and Prosopis integrated into efforts to bolster food security and livelihoods among pastoralist communities.

In Ghana, the *Removing Barriers to Invasive Plant Management in Africa* project was able to forge close working links with another UNEP/GEF project, *Addressing Trans-boundary Concerns in the Volta River Basin and Downstream Coastal Areas*, which had a pre-existing Water Hyacinth Management component. At the regional level, the Removing Barriers project was able to establish close working ties with the African Development Fund, then running a programme on *Integrated Management of Invasive Aquatic Weeds in West Africa*. A similar close relationship was formed in East Africa, between the project's Ugandan operations and the work of the Lake Victoria Environmental Management Programme, set up in 1995 by the governments of Kenya, Uganda and Tanzania with the long-term aim of improving sustainable use of the lake and its resources across all three countries.

In Zambia, the Removing Barriers project could build on the work of an earlier initiative, undertaken as part of the Southern Africa Biodiversity Support Programme funded by the United Nations Development Programme (UNDP), which had prioritised the establishment of information systems and technical guidelines, both regionally and within Zambia, for the management of invasive alien species.

In being networked with the operations of so many different national and regional organisations, the *Removing Barriers to Invasive Plant Management in Africa* project would be able to limit wasteful duplication of effort, while harmonising management approaches and interventions. The project would be able to ensure, for example, that management solutions pursued in relation to alleviating other social problems would not, at the same time, heighten the risk of spreading invasive plant species – and so succeed only in aggravating the social problems (as has happened so often in the past where attempts have been made, for example, to combat the impacts of encroaching desertification on poor rural communities).

Barriers are revisited

By August 2005, the development and planning phases of the UNEP/GEF *Removing Barriers to Invasive Plant Management in Africa* project were nearing completion. A huge amount of data had been gathered on the status of invasive plant species and their impacts in all four participating countries. Invasive species of particular concern to each country had been singled out as priority targets. Pilot sites for management and preventive interventions had been identified. Stakeholders had been consulted. Tie-ups with governments and with organisations running complementary initiatives and programmes had been established.

In the process, a clear understanding had emerged of the barriers that would have to be overcome if these and other countries in Africa were going to be able to sustain the comprehensive National Invasive Species Strategy and Action Plans the project would be developing and helping them to implement. Long-term sustainability was, after all, the overriding objective of the measures the *Removing Barriers to Invasive Plant Management in Africa* project would be instituting. It remained, then, for the project to formulate operational components for an overall strategy that might enable the invaded nations of sub-Saharan Africa to overcome long-standing barriers and to pursue effective long-term programmes of invasive plant management.

The strategies and actions devised to overcome these barriers are the subject of the following chapter …

Dams, such as this one, on the Wonji-Shewa Sugar Estate, Ethiopia, were cleared of Water Hyacinth as a result of project activities ©Arne Witt

Ways and means

Strategies pursued by the *Removing Barriers to Invasive Plant Management in Africa* project

It is often said of development assistance to Africa that what the continent needs, above all, are programmes*, as opposed to projects. A project's success, then, may be gauged from how strong and enduring a legacy it leaves behind in the form of self-sustaining programmes that are able to go on functioning independently long after the project itself has run its course.*

The establishment of such programmes was, from the outset, an essential aspect of the UNEP/GEF *Removing Barriers to Invasive Plant Management in Africa* project. Programmes developed over the course of the project would leave each of the four participating African nations – Ethiopia, Ghana, Uganda and Zambia – with a fully operational long-term National Invasive Species Strategy and Action Plan. Each plan would go on being implemented routinely, as an integral component of the national development and environmental policy frameworks of the host country. This would ensure that gains registered during the project's four-year operational phase could be sustained into the future, while creating scope for similar plans to be incorporated into the long-term sustainable development agendas of other African countries.

To this end, the project had to focus on helping the African countries to overcome barriers of the kind that, in the past, had prevented them from implementing invasive species' programmes of their own. Above all, this meant having to develop **capacity** among individuals and institutions in each of the host nations, particularly with regard to awareness, technical know-how, policy development, the enactment of legislation, cost recovery, networking, and the pooling and exchange of information and of best practices on invasive alien plant species and their management.

Barriers are defined

During the planning phases of the *Removing Barriers to Invasive Plant Management in Africa* project, a clear understanding had emerged of particular barriers that would have to be overcome – if the National Invasive Species Strategies and Action Plans that were to be developed through the project would go on to prove sustainable in the long term. A thorough understanding of all these impediments was of course essential for developing the operational components of an overall project strategy that would result in establishment of effective long-term national programmes of invasive plant management in the pilot countries.

The barriers in question were grouped in four broad categories: a weak policy and institutional environment; a lack of awareness and of access to critical information; inadequate arrangements for prevention and control, and a general lack of capacity.

▶ A weak policy and institutional environment

It immediately became apparent in all four of the participating countries that existing policies, regulations and institutional arrangements for addressing the invasive alien species' threat were inadequate. Attempts that had been made to establish a basis for tackling the problem were inconsistent, poorly coordinated and under-resourced. Not one of the countries had been able to institute a dedicated National Invasive Species Strategy and Action Plan, as required under the Convention on Biological Diversity (CBD). All, though, in their respective National Biodiversity Strategy and Action Plans, recognised invasive species as a serious threat to biodiversity.

In the absence of an authority responsible for harmonising national policy towards invasive alien species, no attempt had been made to coordinate policy across different sectors. Inconsistencies and mixed signals were the inevitable result. So, for example, while the planting of Prosopis (Mesquite) in Ethiopia was being recommended under that country's National Plan to Combat Desertification, the species was at the same time identified as a threat to biodiversity under Ethiopia's National Forestry Research Strategy.

There was confusion too, in the absence of a single coordinating body, over which arm of government should take the lead in addressing issues relating to invasive alien species. Historically, invasive species have in most countries been the concern of the agriculture sector, where the focus, understandably, has been mainly on limiting crop damage by invasive pests, principally insects. Responsibility for implementing CBD protocols, however, generally falls to the environment sector. A lack of coordination between different sectors has, in most African countries, resulted in a worrying lack of decisive action on the ground – underlining the need for a coordinating mechanism through which the invasive alien species' threat might be mainstreamed nationally as a cross-cutting policy issue of concern to all sectors.

Financial constraints in all four nations would have to be addressed, if institutional capacity was to be enhanced. None of the countries had been able to muster sufficient resources to sustain effective invasive alien species' management activities. So cost-recovery mechanisms would have to be developed. Such mechanisms are essential in order to generate the funding required to maintain an invasive species' management programme. Typically, some of the finances required to run a preventive programme are 'recovered' through taxes levied on inspections carried out on imported goods or produce that might pose a national bio-security risk. One of the priorities, then, for the *Removing Barriers to Invasive Plant Management in Africa* project, would be to develop mechanisms of cost recovery for each of the participating countries.

▶ A lack of awareness and of access to critical information

Another manifestation of the weak policy and institutional environments in all four of the host nations was that many decision-makers were unaware of, or had little or no access to, data on invasive plant species, including species that were already wreaking havoc in their countries.

In particular, there was a lack of communication, not only between different arms of government, both national and local, but also between government and the private sector, and between decision-makers and affected communities and members of the public. So, for example, whereas the invasive threat of *Mimosa pigra* was well known in parts of Zambia as long ago as the early 1980s, the Zambian authorities would not become aware of the problem until well into the 1990s.

Similarly, worrying news of the appearance – in the Ruizi River system feeding into Lake Mburo in Uganda and also in pools at Adenta close to Accra in Ghana – of the Water Hyacinth, *Eichhornia crassipes*, had been slow in filtering through to the authorities. A rapid response is generally possible only where a new infestation of an invader of known destructive potential is detected early. So delays in the sharing and exchange of such critical information can be extremely costly, to the environment and to livelihoods and economies, as well as in potential future outlays necessitated by a succession of rearguard containment and control efforts.

In all four participating nations, access to information on native plant biodiversity was limited. In particular, the status of invasive plant species had not been adequately documented. The most comprehensive species lists on offer for national biodiversity hotspots were for mammals and birds. For hotspots with a comprehensive plant list as well, such as the Budongo Forest Reserve in Uganda, no mention is made of the non-native flora occurring in the area, or of the conservation threats this alien flora poses.

The result, even in well-studied conservation areas (such as Budongo), is that the impact of invasive plant species remains poorly understood. One alien plant invader that has been studied at Budongo is the Paper Mulberry, *Broussonetia papyrifera*. Yet reconnaissance work undertaken there during the preliminary phases of the *Removing Barriers to Invasive Plant Management in Africa* project found that infestations of another alien tree species – the Spectacular Cassia, *Senna spectabilis* – were having a significantly greater impact on Budongo's biodiversity.

Another information-related failing identified by the project was the inability, on the part of national institutions in the participating countries, to take advantage of, or to contribute to, the wealth of information posted on-line and available globally on invasive species and their management. Whereas all the national executing agencies had websites, none of these sites contained data on invasive alien species and none was linked to well-established global information sources such as those of the Global Invasive Species Programme and the IUCN's Invasive Species Specialist Group. This meant that people in Africa were missing out on a very considerable existing body of global knowledge on a wide range of common problematic species, such as *Lantana camara* and *Mimosa pigra*.

Broussonetia papyrifera poses a significant threat to biodiversity and water resources in the Afram Headwaters Forest Reserve, Ghana ©Arne Witt

Inadequate arrangements for prevention and control

All four host countries, through their respective plant quarantine facilities, had some measures in place for preventing the introduction of invasive plant species. The main focus, however, was on intercepting agricultural pests. Basic risk analyses were being carried out, but again capacity was limited, particularly with regard to the assessment of environmental risks and threats to biodiversity.

None of the countries had systems in place for detecting and monitoring invasive plant species that might already have breached the rudimentary national defences and so gained entry. Not surprisingly, in view of the absence of early detection systems, there was no rapid response plan either that might enable the countries to eradicate potentially destructive infestations of new invaders.

The response to invasions was in most cases slow and inadequate, although some control measures, once applied, had been successful. The use of biocontrol agents to manage infestations of the Water Hyacinth, in Lake Victoria for example, had been extremely effective. There, it had been possible over a ten-year period (1995–2005) to reduce the extent of the hyacinth infestation by almost 85%, from 20,000 hectares to little more than 3,000 hectares. It had taken all of six years, though, for the menace of the hyacinth, which had entered the lake in 1989, to be addressed – despite the proven record elsewhere of readily available biocontrol agents. In Ethiopia, where biocontrol had never been practised, no response had been forthcoming, more than 15 years after Water Hyacinth infestations were detected in the Awash River catchments near Addis Ababa.

There was often a reluctance, moreover, to apply proposed control measures in response to infestations of 'conflict species' (species introduced intentionally, that is, with anticipated benefits in mind, but which had turned out instead to be an invasive menace). *Prosopis juliflora*, for example, was – and in places still is – promoted as a beneficial tree. As such, it was widely introduced into Ethiopia in the 1970s. There, it was expected to provide people with shade, fuel wood and building materials and also with supplementary fodder for their livestock herds, while at the same time helping to curb encroaching desertification in over-grazed arid and semi-arid areas. Instead, the species had formed impenetrable shrubby thickets, invading watercourses, lowering the water-table and thereby indirectly starving plants of other species of moisture and nutrients, creating what are known as 'green deserts'.

Opinion, though, on the merits and demerits of Prosopis was still divided in some quarters. In Ethiopia, as in other parts of the species' invasive range in Africa, there had been no attempt to resolve such conflicting perceptions. There was, for example, no regulatory framework in place through which costs and benefits of this and other conflict species might be evaluated scientifically – and ruled upon accordingly.

A general lack of capacity

In all four participating countries, the wherewithal and the resources – institutional, human, financial, and physical – available for addressing the invasive species' threat were far from adequate. In Ghana alone, there are no fewer than 48 *official* national entry points. Most were found to be under-staffed, under-resourced and inadequately equipped, relative to the enormous daily inflow of traffic and material. Here, as along international borders elsewhere in Africa, there are many unofficial entry points too, providing additional pathways for invasive species via the steady influx of smuggled goods and materials, which of course evade even cursory inspection.

The national plant protection organisations within each host country had received some capacity-building support. This support had in some countries given rise to the promulgation, on paper, of impressive regulations, including – in Ethiopia – the Plant Quarantine Council of Ministers Regulation No. 4 of 1992, under which

Pasture for Ankole cattle is threatened by the invasion of *Cymbopogon nardus* in Uganda ©Arne Witt

the country's Ministry of Agriculture and Rural Development was empowered to enforce a range of strict controls on trade in plants and plant products. Unfortunately, however, for want of both the means and the capacity, the ministry in question had been unable to act on these powers.

Technical cooperation projects funded by the Food and Agriculture Organisation (FAO) of the United Nations had (except in Ghana) provided the respective national plant protection organisations with further capacity-building support. This assistance had seen risk assessment procedures introduced as a safeguard against the potential introduction of damaging agricultural crop pests in legally traded goods and produce. The measures had not been adapted, however, for use in analysing risk in relation to admitting potentially invasive alien plant species.

A lack of capacity had in some instances, moreover, prevented promising control efforts, developed in small-scale trials, from being extrapolated on to a field scale. In Uganda, for example, an extremely cost-effective method for the integrated control of infestations of the invasive lemongrass species False Citronella, *Cymbopogon nardus*, had been pioneered in small-scale trials. The method would potentially reduce overall control costs from about US$ 175/hectare to just US$ 25/hectare. But implementation had been thwarted by poor networking and organisational skills, which meant there had been no follow-up.

A four-pronged strategy is pursued

By December 2005, when the *Removing Barriers to Invasive Plant Management in Africa* project was launched, there was a clear strategy in place for operations within each of the host nations. The strategy was based, in each case, on four components – one component for overcoming each of the four sets of major barriers that had been identified during the project's development and planning phases.

The project's four operational components, although treated separately for ease of management and for purposes of accountability, were nevertheless implemented in an integrated manner, taking into account the many obvious linkages and overlaps between any one of the components and another. A fifth component was added to coordinate management activities across the project as a whole.

The goals of the project's four operational components were: first, to strengthen the enabling policy and institutional environment of each country with respect to the management of invasive alien plant species; second, to raise awareness and facilitate access to, and exchange of, critical information relating to invasive plant species and their management among all stakeholders; third, to devise and implement prevention programmes and control strategies for managing invasive plant species, and fourthly, to build, in each of the participating countries, the capacity required for sustainable invasive alien plant management.

1. Strengthening the enabling policy environment

A National Invasive Species Strategy and Action Plan (or NISSAP) would, under this component of the project, be developed for – and implemented in – each of the host nations. To this end, the *Removing Barriers to Invasive Plant Management in Africa* project would, in each of the countries, review all existing policies, plans, laws and regulations that included, or which should include, elements relating to invasive alien species. The review process would be conducted in consultation with all stakeholders, including legislators and policy-makers and representatives from different sectors and arms of government, both national and local, as well as from private enterprise and local communities.

Policy guidelines and recommendations arising from these stakeholder meetings and workshops would in turn be conveyed to decision-makers at the highest level, so raising the profile of the invasive species' threat on each country's political agenda.

A case would be made for the allocation of much-needed resources to the management of invasive species. Targeted lobbying would further seek to facilitate the enactment of new legislation, which in some cases – such as the proclamation in Ethiopia on the importation of biocontrol agents for managing serious Water Hyacinth infestations – had already been drafted and was under consideration.

In each host country, a national coordinating mechanism would be installed. This mechanism would take the form of an 'apex body' responsible for making sure that adopted national policy towards invasive species could be harmonised and applied consistently across all sectors and at all levels. This would help to eliminate conflicts of interest and needless duplication of effort.

The apex bodies would, through national steering committees, be hosted initially by the national executing agencies – that is, by the Ethiopian Agricultural Research Organisation (now the Ethiopian Institute of Agricultural Research); by the Council for Scientific and Industrial Research (CSIR) in Ghana; by the National Agricultural Research Organisation in Uganda, and by the Environmental Council of Zambia (now known as the Zambian Environmental Management Agency). In time, however, as the institutional structures of each country were assessed, a permanent home would be found for each

On the Parthenium trail: Geoffrey Howard, of the IUCN, with a team of young assistants during a Project field trip to Ziway, Ethiopia ©Arne Witt

apex body, in what was adjudged to be the best-placed national organisation.

Close to the pilot sites within each of the host countries, sub-national coordinating mechanisms would also be established. These bodies, representing stakeholders from local government, as well as from affected rural communities and private enterprise, would be responsible for ensuring that the invasive plant management programmes introduced on site were sustained, in liaison in each case with the national apex body.

The cost-recovery mechanisms developed and implemented in each of the host countries would generate the revenue streams required to sustain these programmes, so reducing their dependence on central government funding.

2. Raising levels of awareness and of access to information

A general lack of awareness with regard to the problem of invasive alien plant species was perhaps the single biggest impediment facing the *Removing Barriers to Invasive Plant Management in Africa* project. The awareness campaigns mounted under this component of the project would therefore be critical to the success of the initiative as a whole.

A wide range of materials, designed to inculcate awareness among stakeholders at all levels, was developed following the planning phases of the project. The materials were produced in various media and in a number of different languages, including all the major languages used in and around each of the project field sites. Posters, leaflets and other printed materials would be displayed at and disseminated from community centres and at government offices. Short films, also made available on DVD's for dissemination, would be shown on national television, as well as in rural schools and training colleges and at social centres in the project areas. Discussion programmes would be aired on local radio stations, along with jingles on invasive species. Training manuals and management guidelines would be made available. Regular talks, workshops and discussion forums and think-tanks would be organised, bringing together a cross-section of different stakeholder groups. The emphasis would be on cooperative actions that might be taken both to prevent the influx of alien plant invaders and to manage their existing infestations.

Available information on established existing global websites and databases, such as those of the Global Invasive Species Programme; the Global Invasive Species Database (GISD) hosted by the IUCN, and CABI's Crop Protection Compendium, was adapted for use in each of the participating countries. This information, suitably re-packaged for dissemination in each nation, would be incorporated into the websites of the four national executing agencies, together with links to other key information resources, both international and regional. As part of the project's wider 'scaling up' objective, there would be provision for outreach activities involving the dissemination of information and awareness in some neighbouring countries as well.

3. Implementing prevention and control programmes

The preventive risk assessment procedures in all four countries would be expanded under this component of the *Removing Barriers to Invasive Plant Management in Africa* project. Environmental risks, assessed under conventional pest risk analyses, would be extended to include the evaluation of all weeds for potential invasiveness as well. Monitoring and reporting systems for the early detection of invasive alien plant infestations, particularly in vulnerable ecosystems where the threat to biodiversity was most pronounced, would be developed and implemented. Such early detection mechanisms might in some instances make eradication of new invaders possible; so a follow-up rapid response strategy would also be developed for incorporation in each country's National Invasive Species Strategy and Action Plan.

Databases documenting the status and impacts – ecological, social, and economic – of invasive alien plant species in each host nation would be initiated. The databases, essential for monitoring purposes, would include the findings of additional country-wide surveys, building further on the baseline data gathered and compiled during the project's preliminary planning phases. Provision would be made for regular updating of these national invasive species' databases.

All ecosystem-based invasive species' management actions introduced during the project, including the control and habitat rehabilitation programmes initiated at pilot sites, would draw wherever possible on a participatory approach directly involving affected stakeholder groups. This hands-on involvement would help to consolidate awareness at the local level, while enhancing the longer-term sustainability of control programmes implemented under this component of the project. Local stakeholder groups would also participate directly in the subsequent monitoring process, giving them a sense of ownership over community benefits engineered through the control interventions. The monitored effects of each intervention would be communicated nationally, so other affected communities might be encouraged to embark on similar programmes.

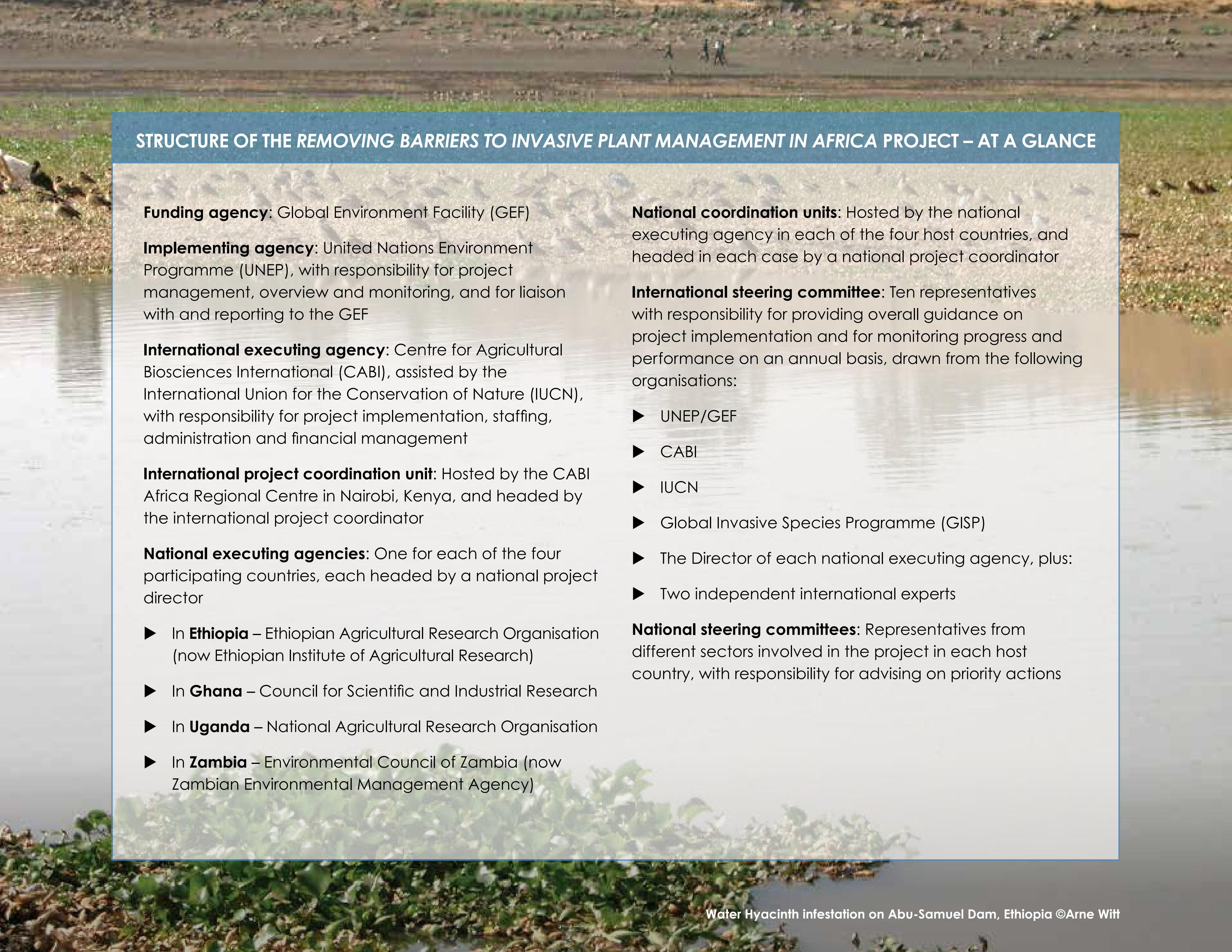
4. Building capacity for sustainable invasive plant management

Training would of course be essential for consolidating and building capacity at every stage in the implementation process. A wide range of training needs, identified during the planning phases, would be met under this component of the *Removing Barriers to Invasive Plant Management in Africa* project.

The training would take the form, not just of intensive courses for existing staff at important interfaces in the host countries, such as customs inspection and quarantine facilities and government land- and resource-management institutions; it would also include modules for incorporation into courses – on natural-resource management and the environment, for example, and conservation – being offered by technical training colleges and other academic institutions, including high schools. Project support for post-graduate students working on invasive species-related topics, meanwhile, would help to expand and enhance the pool of expertise in each of the participating nations.

The aim, as with other aspects of the project, was to ensure that knowledge and skills relating to invasive alien plant species and their management could be sustained into the future, as part of the wherewithal of prospective future managers and their staff. On-site training for local communities would be another important aspect of the capacity-building process.

To this end, educational packages were designed for a variety of target



STRUCTURE OF THE *REMOVING BARRIERS TO INVASIVE PLANT MANAGEMENT IN AFRICA* PROJECT – AT A GLANCE

Funding agency: Global Environment Facility (GEF)

Implementing agency: United Nations Environment Programme (UNEP), with responsibility for project management, overview and monitoring, and for liaison with and reporting to the GEF

International executing agency: Centre for Agricultural Biosciences International (CABI), assisted by the International Union for the Conservation of Nature (IUCN), with responsibility for project implementation, staffing, administration and financial management

International project coordination unit: Hosted by the CABI Africa Regional Centre in Nairobi, Kenya, and headed by the international project coordinator

National executing agencies: One for each of the four participating countries, each headed by a national project director

- In **Ethiopia** – Ethiopian Agricultural Research Organisation (now Ethiopian Institute of Agricultural Research)
- In **Ghana** – Council for Scientific and Industrial Research
- In **Uganda** – National Agricultural Research Organisation
- In **Zambia** – Environmental Council of Zambia (now Zambian Environmental Management Agency)

National coordination units: Hosted by the national executing agency in each of the four host countries, and headed in each case by a national project coordinator

International steering committee: Ten representatives with responsibility for providing overall guidance on project implementation and for monitoring progress and performance on an annual basis, drawn from the following organisations:

- UNEP/GEF
- CABI
- IUCN
- Global Invasive Species Programme (GISP)
- The Director of each national executing agency, plus:
- Two independent international experts

National steering committees: Representatives from different sectors involved in the project in each host country, with responsibility for advising on priority actions

Water Hyacinth infestation on Abu-Samuel Dam, Ethiopia ©Arne Witt audiences and groups. Field outings for parties of schoolchildren and their teachers would be a key element of the project's long-term awareness- and capacity-building mission, for example. At the national level, meanwhile, arrangements would be made to facilitate the involvement of delegates in international forums on invasive species.

Some essential items of equipment would also be provided, with a view especially to bolstering the interceptive capacity of inspection units at border crossings.

National task forces are assembled

The implementation of a four-pronged strategy on this scale called for the setting up of a strong, well organised task force within each participating country. To this end, four national work teams were assembled by the *Removing Barriers to Invasive Plant Management in Africa* (RBIPMA) project's international coordination unit, hosted by its principal executing agency, the Centre for Agricultural Biosciences International (CABI), with assistance from executing support agency, the International Union for the Conservation of Nature (IUCN).

The task force in each country would include a national coordination unit, to be embedded initially within the national executing agency, but operating independently of it. Each national coordination unit would be headed by a full-time national project coordinator, a post funded by the Global Environment Facility (GEF). Each national coordination unit would be headed by a full-time national project coordinator, a post funded by the Global Environment Facility (GEF). Each national project coordinator would report directly to the international coordination unit, hosted by the CABI Regional Centre in Nairobi, Kenya, on the delivery of all project outputs. The director or head of the institution hosting each national executing agency would serve as national project director, overseeing project activities and reporting to the international steering committee, which would be convening annually.

In each country, there would be a broad-based national steering committee, drawn from different sectors and including representatives

Cymbopogon management field trial in Uganda: National Project Coordinator Dr Gadi Gumisiriza (second from left) consults with fellow team members ©Geoffrey Howard

from government departments, from the private sector and from civil society. Work teams responsible for activities at each of the pilot sites would include representatives from all local stakeholder groups. Technical guidance within each country would be provided by a specially constituted national advisory committee, working in liaison with the national coordination unit for the project and its national executing agency, and with guidance from both CABI and the IUCN.

▶ In Ethiopia

The Ethiopian Institute of Agricultural Research (or Ethiopian Agricultural Research Organisation, as it was then called), within the country's Ministry of Agriculture and Rural Development, would be Ethiopia's national executing agency for the RBIPMA project.

The Institute is part of an extensive network collectively known as the Ethiopian Agricultural Research System, which operates more than 60 research centres country-wide, and whose mandate encompasses pastoralist and agro-pastoralist land uses, as well as farming-related programmes and technologies. As an established and widely networked organisation, the Institute was well placed to serve as the project's national executing agency – particularly inasmuch as the project's principal focus in Ethiopia would be on addressing the impacts of invasive alien species on the productivity of agricultural and pastoralist systems, as well as the impacts on biodiversity and human health and livelihoods in rural communities.

The national coordination unit (or NCU) in Addis Ababa, with a full-time staff of four, would be responsible for the project's day-to-day operations. In all, there would be seven subsidiary task units, including local coordination sub-committees at two of the country's three pilot sites. At another site, near Wonji, a working partnership was established with the Shewa Sugar Estate. A six-member advisory committee had been assembled to provide technical guidance.

▶ In Ghana

The Council for Scientific and Industrial Research, based in Accra, would be Ghana's national executing agency for the RBIPMA project. The Council was then operating under the Ministry of Environment, Science and Technology, but would subsequently be placed under the administrative aegis of Ghana's Ministry of Local Government, Rural Development and Environment.

The Council has a long and venerable history in Ghana, dating back to 1958. The 13 institutes it embodies are engaged in a broad range of scientific and technological pursuits, including research and development in agriculture, animal husbandry, food and nutrition, water, forestry, and plant genetics, as well as in a number of industries. Some of these institutes had already been involved in the management (both control and prevention) of alien plant invasions. Indeed, it was laboratories here which had overseen the deployment in Ghana of several biocontrol agents, ranging from various weevils and other insects in use for controlling infestations of water weeds to the leaf-feeding moth *Pareuchaetes pseudoinsulata*, used to control terrestrial infestations of Siam (Triffid) Weed, *Chromolaena odorata*. The Council's Plant Genetic Resources Research Institute, meanwhile, had a history of working on biodiversity conservation, and was also developing gene banks of tropical plants.

The Council, then, was an obvious choice both for the role of national executing agency and as the seat of the project's national coordination unit of six full- and part-time staff. For the coordination of activities at the pilot localities, the project was able to operate through existing organisations – in the shape of the Volta River Authority (for the site on the Oti Arm of Volta Lake) and of the Forestry Research Institute of Ghana (in the case of the Afram Headwaters Forest Reserve). This was desirable from the point of view of sustainability, and would also save time and prevent duplication of effort. A 12-member national steering committee made up of representatives from various government departments and non-governmental organisations would provide technical guidance, while ensuring that all invasive alien species-related interventions were harmonised across sectors.

In Uganda

Uganda's National Agricultural Research Organisation (NARO), based in Entebbe and affiliated to the country's Ministry of Agriculture, Animal Industry and Fisheries, was to serve as national executing agency for the RBIPMA project.

As the body primarily responsible for coordinating financing, management and delivery of agricultural research services in Uganda, NARO is an important part of the country's National Agricultural Research System established in 2005 in line with the Plan for the Modernisation of Agriculture introduced under Uganda's then-newly adopted National Agricultural Research Policy. The Research System represents the interests of a large and varied cross-section of institutions and stakeholders from both the public and private sectors, ranging from academic institutions and farmers' groups to civil society organisations and business corporations. The overriding goal is one of bettering lives and livelihoods through practices that are environmentally sustainable.

As such, NARO has long been at the forefront of efforts in Uganda to combat the damaging impacts of invasive alien plant species, making the organisation ideal as a national executing agency and as the hub for the project's national coordination unit – which again would have a staff of six. The 12-member national steering committee in Uganda would include representatives from the Ministry of Finance; the Ministry of Agriculture, Animal Industry and Fisheries; the National Environment Management Authority; the Ministry of Water, Lands and Environment; the Uganda Wildlife Authority, and the Faculty of Forestry and Nature Conservation at Makerere University, as well as representatives from selected non-governmental organisations, commercial enterprises and community groups from the pilot sites in the country.

In Zambia

The Environmental Council of Zambia (or the Zambian Environmental Management Agency, as it is now), affiliated to the Ministry of Tourism, Environment and Natural Resources, would serve as the national executing agency for the RBIPMA project.

The Environmental Council was established in 1992 as the Zambian Government agency responsible for overseeing sustainable management and use of the country's natural resources. It was – and, under its new name, still is – the coordinating body for all environment-related policies and practices in Zambia. Its functions include advocacy, policy formulation and enforcement, and the carrying out of environmental impact assessments. It has been instrumental, especially, in raising the profile within Zambia of the ecological and economic threats posed by invasive alien plant species.

As such, the then-Environmental Council was particularly well placed to serve as the national executing agency for the project in Zambia and as host to the project's national coordination unit and its full-time staff of six. A 14-member-strong national steering committee, including conservation authorities from government institutions, NGOs and the private sector, would contribute expert technical guidance.

In Zambia, two pilot site coordinators were appointed – one, based in Livingstone and operating under the National Heritage Conservation Commission, for the site at Mosi-oa-Tunya; and the other, operating under the Zambia Wildlife Authority, for the site in the Lochinvar National Park. Pilot site management committees would include community representatives from surrounding areas as well.

The Government of Zambia, moreover, undertook to contribute additional project funding, over and above the cost-sharing agreed to under the project's initial work plans. This additional funding – amounting to about US$ 500,000 – was to be used specifically for clearing Mimosa

Project participants met on a regular basis, this time in Ghana ©Felix Akpabey

pigra from infested areas of the Lochinvar National Park in the country's Southern Province. (In the event, the additional funding would help to ensure that some 800 hectares of the weed could be cleared from the floodplain.)

Inception

The inception of any project can be a critical juncture. Conditions on the ground have a way, often, of confounding even the best-laid plans. In the case of the RBIPMA project, which would be operating in four widely separated African countries over a four-year period, contingencies of one sort or another were bound to arise, calling for strategic adjustments and changes of approach along the way.

From the outset, then, a degree of flexibility had to be built into the planning of the project. Accordingly, there would, in the early part of 2008, a little more than two years into the project's operational cycle, be a thorough and independent Mid-Term Review, during which progress made under all components of the project would be evaluated, and through which project actions might, where necessary, be re-focused or realigned.

After a gestation period of almost 18 months, the *Removing Barriers to Invasive Plant Management in Africa* project finally got under way, as planned, in December 2005. How the project went on to fare in

Uninvaded landscapes in East Africa are a major drawcard for tourists ©Arne Witt

Actions and advances

Outcomes of the project in Ethiopia, Ghana, Uganda and Zambia

The UNEP/GEF Removing Barriers to Invasive Plant Management in Africa project was to have been implemented within a four-year period ending in December 2009. In the event, the life-span of the project was extended twice – first to July 2010, and then to June 2011. The extensions, which entailed no additional project expenditure, arose from the need to complete some of the procedures initiated between 2005 and 2010, during the project's core implementation phase.

Progress in the four African countries, over the course of the project as a whole, was far from uniform. Yet by July 2010, each country had met most of the project's major objectives. A National Invasive Species Strategy and Action Plan, or NISSAP, had been developed in each country, and these Plans were all in the process of being ratified. Draft amendments addressing the invasive species' threat had been approved for incorporation into each country's National Biodiversity Strategy and Action Plan.

A hosting institution to accommodate each nation's 'apex body' – the unit set up to coordinate national policy on invasive alien species (IAS) and their management – had been identified and approved, and the necessary structural arrangements were under way. The governments of three of the countries had committed themselves to funding a continuation of management programmes instituted through the project.

Methods of cost-recovery for the long-term financing of self-sustaining invasive species' management programmes had been developed for each country, along with guidelines for implementing the measures. Systems of Risk Assessment and of Early Detection and Rapid Response had been devised, and some of the new Risk Analysis procedures were in the process of being applied. Essential items of equipment, requested and installed during the project, had bolstered the interceptive capacity of inspection units at entry points and at border crossings into some of the countries, making it easier for inspection teams to identify and to prevent the introduction of invasive or potentially invasive species.

Communications Strategies, in place in all four countries, were proving highly effective as avenues for disseminating information and raising levels of awareness on invasive alien species and their management. As a result, there had been a dramatic increase in media coverage of the issue, which in turn was generating further public interest and concern, both within each country and regionally. Websites too had been created in each country and these, although poor to begin with, were being upgraded regularly. Participation in international conferences, workshops and other forums and events, arranged through the project, had facilitated the exchange of ideas and of best practices regarding the management and prevention of alien species' invasions.

Management and control interventions implemented at the pilot field sites in each of the four nations had all been demonstrably successful. The interventions – guided by thorough Ecosystem Management Plans and Environmental Impact Assessments carried out upon initiation of the project – had at some sites resulted in the removal of targeted plant invaders from extensive tracts of infested habitat. Parts of infested sites within protected areas, on being cleared of alien invaders, had been rehabilitated (through the planting of native species) and were showing obvious signs of recovery, reflected in impressive biodiversity gains.

Training programmes had been initiated and were being applied in all four of the host countries. Hundreds of stakeholders had attended intensive training courses on the biology of invasive alien plant species and their management. The beneficiaries included government policy-makers and legal practitioners, agricultural officers and support staff, quarantine supervisors, and conservation and land- and resource-use managers, as well as farmers' and pastoralist groups from vulnerable communities and game rangers and scouts working in conservation areas. Training manuals and management guidelines had been distributed, along with other educational materials, including eye-catching leaflets and posters.

Modules on invasive alien species had been assimilated into the coursework of technical training colleges and other academic institutions, including high schools, in some of the participating countries. More than 40 university students had embarked, during the project's implementation phase, on post-graduate studies specialising in invasive alien species. Some had since completed their MSc and PhD degrees, and – with help from the project – had been able to get their research findings published in international journals.

The resulting increases in capacity and in levels of national awareness had greatly boosted the wherewithal of each participating country to address the impacts of, and to manage, problematic invasive alien plant species. In the process, the *Removing Barriers to Invasive Plant Management in Africa* (RBIPMA) project was able to help all four African countries meet strategic goals set out under two Biodiversity Targets prioritised by the Global Environment Facility, namely: *Mainstreaming Biodiversity Concerns in Productive Landscapes and Sectors* and *Generation and Dissemination of Best Practices for Addressing Current and Emerging Biodiversity Threats*.

Both targets are cornerstones of efforts providing for effective implementation globally of Article 8(h) of the Convention on Biological Diversity (CBD) obliging all member nations "… as far as possible and as appropriate, to prevent the introduction of," and "to control or eradicate those alien species which threaten ecosystems, habitats or species". Both are endorsed, moreover, under Target Number 9 of the Aichi Biodiversity Goals adopted at the tenth meeting, in Nagoya, Japan, of the Conference of the Parties to the CBD. This stipulates that, "By 2020, invasive alien species and their pathways are identified and prioritized," and that "priority species are controlled or eradicated, with measures in place to manage pathways and so prevent their introduction and establishment".

The success of the RBIPMA project can be gauged from how, between 2005 and 2010, each of the four nations was able simultaneously to meet, or to exceed, most of the ambitious benchmark indicators envisaged under 35 essential outputs (and their many associated activities) contributing to the four major project outcomes …

Outcome 1 – Stronger IAS policy and institutional structures

Outputs under this component of the RBIPMA project included development of the respective National Invasive Species Strategies and Action Plans; mainstreaming of IAS-related issues across sectors in the national and provincial development agendas of all four countries; incorporation of IAS considerations into each country's existing National Biodiversity Strategy and Action Plan; establishment of the 'apex bodies' for coordinating national IAS policy and practice, and the setting up of cost-recovery mechanisms for financing national IAS management activities and programmes.

Progress towards realising all these outputs was gradual. The introduction of new policy, or of amendments to existing policy, can be a lengthy process in any country, especially where some institutional restructuring is also called for. Such changes are the culmination of a succession of consultative meetings involving different sectors, national authorities and arms of government. The drafting and eventual approval of new policy, through an Act of Parliament, can also be a protracted process. So it was perhaps no surprise that only a few of the agreed new national policies on invasive species could be formally adopted within the project's operational time-frame.

In **Ethiopia**, sweeping government and institutional reforms entirely unrelated to the project meant that inception had to be delayed for almost one year. Inevitably, this held back realisation of some project goals, despite belated efforts on the part of the Ethiopian national coordination unit (NCU) to make up for the lost time. In consequence, Ethiopia's draft National Invasive Species Strategy and Action Plan (NISSAP) had, as of June 2011, yet to be formally endorsed. But the Government of Ethiopia had committed itself to completing the implementation process, and would also be allocating funding to support the national apex body and to extend the life of IAS management programmes beyond the project period.

In **Ghana,** a NISSAP was formally approved and adopted during the project's core implementation phase. An amended National Biodiversity Strategy and Action Plan (or NBSAP) was also formally endorsed. Both these advances were achieved after surmounting previously intractable bureaucratic hurdles, encountered during the early stages of the RBIPMA project.

Primate habitats in Africa are becoming increasingly threatened by invasive species ©Arne Witt

CHAPTER SEVEN

In **Uganda**, many of the project's activities and structures are now established mainstream instruments. The apex body responsible for coordinating national IAS policy is to be housed within the Entebbe-based National Agricultural Research Organisation (NARO). Ratification of the country's NISSAP, although pending, is expected to follow. Uganda has a strong institutional platform for applying the Plan, once ratified. The Government of Uganda has committed itself to underwriting IAS management programmes in the country for another five years.

In **Zambia**, promulgation – in the wake of the RBIPMA project – of the revised Environmental Management Act, No. 12 (of 2011), has considerably strengthened the country's regulatory framework for managing invasive alien species. The revised Act is to be enforced by the newly constituted Zambia Environmental Management Agency (ZEMA), which has replaced the Environmental Council of Zambia (ECZ) as the body responsible for IAS management issues. The new Act contains wide-ranging provisions for preventing the influx of IAS and for combating their spread, and includes deterrents in the form of punitive fines for non-compliance.

Zambia benefited from having a dynamic project NCU, and from a high degree of government commitment and backing, which extended to substantial supplementary funding support for the project.

New IAS guidelines are to be incorporated in the National Biodiversity Strategy and Action Plans (NBSAPs) of Zambia, Ethiopia and Uganda, when next these Plans come up for review. The revised NBSAPs are expected to reflect the 2010 Aichi Targets set in Nagoya, Japan, at the tenth meeting of the Conference of the Parties to the CBD.

The cost-recovery mechanisms developed under this component of the project have yet to be fully implemented in the four countries. In the short term then, IAS activities and programmes in all four countries would, to a large extent, have to rely on direct government funding support. Each nation was to review its options, however, and would be exploring ways of generating additional revenues through a range of taxes and levies (including, possibly, a water-use levy to cover the costs of removing thirsty invasive alien plants from water catchments).

Charges for carrying out phytosanitary inspections and import risk assessments would also be reviewed, with the aim, in the longer term, of being able to reduce the level of dependence in each country on central government funding.

Outcome 2 – Expanded IAS knowledge and awareness

Outputs under this component of the project were geared towards raising the public profile of the invasive alien species' threat through the popular media and through the development and promotion of accessible national IAS information systems and services.

Particular emphasis had been placed on compiling databases and generating user-friendly websites listing and describing the principal invasive plant species present in each country and their respective impacts, while also showing their distribution. The intention was to integrate all the national information, via links, into broader regional and global IAS websites and databases. Each national website was to be monitored, moreover, so its usefulness could be gauged from the number of 'hits' registered.

In the event, the pre-set target indicators for some of these outputs proved overly ambitious. Other outputs, based on public-awareness and communications campaigns aired on radio, or shown on television, or which involved the dissemination of IAS information in newspapers, on posters and in brochures, or though workshops, 'road shows' and seminars, all proved highly effective, however – particularly among communities living in or around the pilot sites.

Some of the project's more successful community activities took the form of live debates aired on local radio stations. One especially animated debate, in Zambia, saw two competing groups of schoolchildren – one for invasive alien plants, and the other against – vying to win over audiences. Contests like this one were especially popular among communities wherein many of the participating schoolchildren were known to the listeners.

Functional IAS websites, developed over the course of the RBIPMA project, have since been partially upgraded. The four sites – posted on **www.eiar.gov.et** for Ethiopia; on **www.csir.org.gh** for Ghana; on **www.naro.go.ug** for Uganda, and on **www.necz.org.zm** for Zambia – are all much simpler than originally envisaged, and all need to be developed further and expanded beyond the scope of project activities alone, if they are to conform to international standards.

At present, these websites feature only some of the more notorious plant invaders found in each nation, along with basic information on impacts and some distribution notes. Country maps showing the distribution of these and other invasive alien plant species have since been prepared by the CABI Regional Centre in Nairobi, Kenya, and are to be incorporated into the web pages, together with additional data.


Creeping Sensitive Plant (*Mimosa diplotricha*) is having a significant impact on livelihoods and biodiversity in western Ethiopia ©Arne Witt

It was not feasible, during the time-frame of the project and within the limits of the resources allocated, to complete the country-wide IAS surveys that had been planned, although work towards a comprehensive database for Uganda has continued and, come 2013, this was nearing completion. The logistics and the expense of carrying out such surveys, not to mention the added capacity and expertise required, had been underestimated in the project's preliminary planning and budgeting phases.

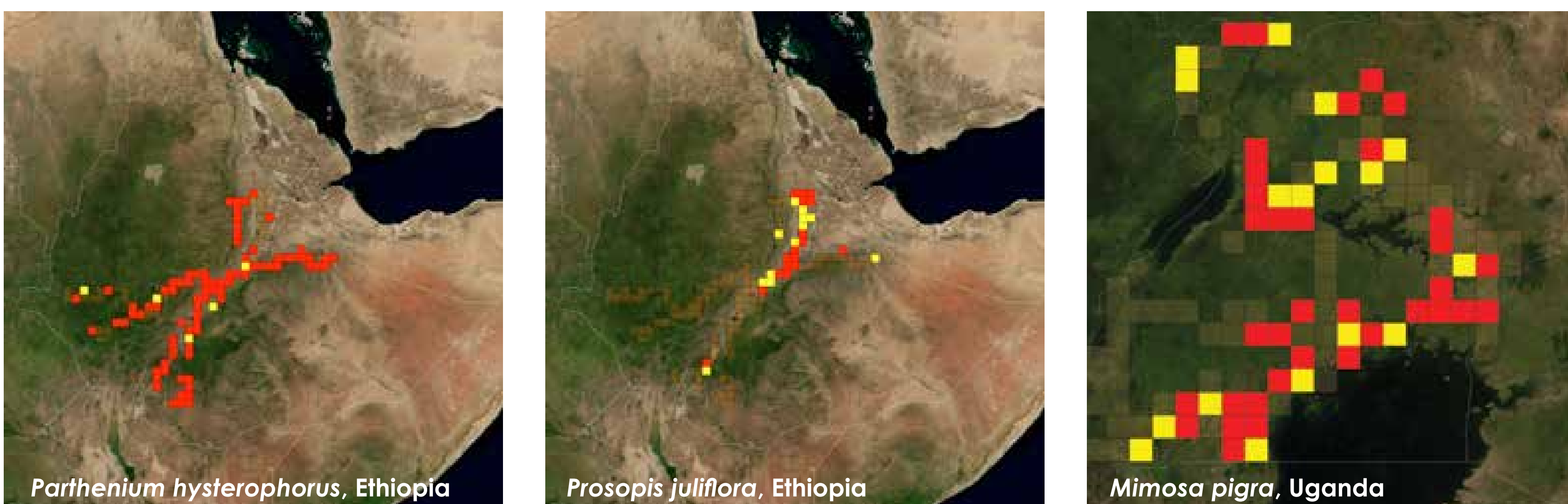
Increases in the levels of IAS awareness among populations in the host countries as a direct result of project activities – another of the stipulated RBIPMA outputs – proved difficult to verify scientifically, at least in any broad, national sense. 'Spot' awareness impact assessments, based on questionnaires distributed before and after the project, showed that local IAS knowledge and awareness in some areas may have increased by as much as 45%. Awareness, though, in other areas, particularly non-invaded zones (where the need for IAS pre-emptive measures is paramount) did not increase significantly. Clearly, higher levels of investment in public communications are required, if national awareness is to pick up. Convincing people, whether in rural communities or in central government, of the reality of an *impending*, as opposed to an actual, invasive threat has remained problematic.

Effectiveness of the national IAS websites – where the goal, post-establishment, had been to achieve an increase of 10% per annum in the number of 'hits' – has also been difficult to monitor, given the slower-than-expected development of these sites. Web citations, though, have been increasing steadily. Casual searches in July 2011 via the Google search-engine (using the keywords 'Invasive plant species, Ethiopia, Ghana, Uganda, Zambia') yielded multiple references to the RBIPMA project and to the IAS websites of the respective nations within the first five cited links. This was a marked improvement on the findings of earlier searches carried out in 2010.

References and links to some of the major global IAS websites and databases are included on the national IAS web pages. Delays in compiling and in verifying some of the information posted on the national websites has meant, however, that links to these sites have yet to be incorporated as cross-references on the international IAS websites. The verification process is continuing, and cross-references are expected to appear on these global sites in 2014. Such references have already been included in CABI's Invasive Species Compendium.

The delivery of presentations from the four African countries at both regional and international IAS forums was another of the project's information-related objectives. In the event, joint presentations and exhibits relating to the project and its country-by-country activities were made at a number of major conferences. These included both the Eighth and Ninth Conferences of the Parties to the Convention on Biological Diversity (CBD), held in 2006 and 2008 in Brazil and Germany respectively, and (in 2009, in Stellenbosch, South Africa) an international conference on the Ecology and Management of Alien Plant Invasions. Project staff from Uganda also went on to attend the International Biosecurity Conference in Brisbane, Australia, early in 2010.

Country delegations were able to participate, moreover, in several international workshops hosted across Africa by the Global Invasive Species Programme (GISP). Topics covered at



Distribution of selected invasive plant species (not all regions in each country were surveyed). Key: Not present Present and/or naturalized Invasive.

these workshops included *Economics and Invasive Species* (the subject of a series of GISP meetings held in southern and East Africa between 2006 and 2008), and *Drafting Legal and Institutional Frameworks for the Management of Invasive Species* – the subject of another series of meetings held in Nairobi, Kenya, in December 2007; in Lusaka, Zambia, in June 2008, and again in Entebbe, Uganda, in November 2008.

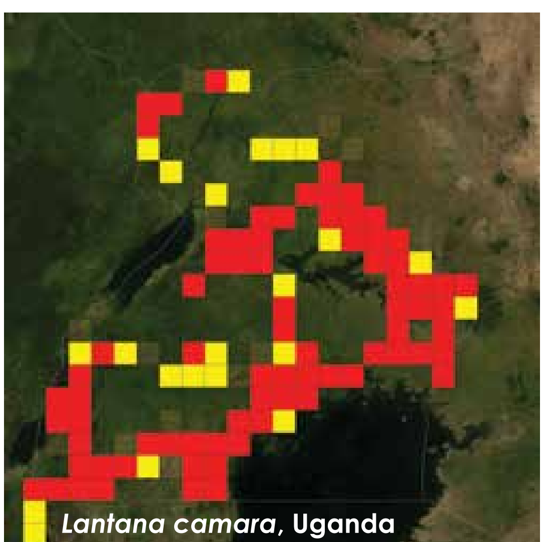
Project delegations from both Ghana and Zambia were able, in addition, to make presentations at regional forums organised and funded by Economic Community of West African States (ECOWAS) and the Southern African Development Community (SADC) respectively. At two sites straddling the Zambia–Zimbabwe international border, a new trans-boundary IAS initiative was established, with assistance from the International Union for the Conservation of Nature (IUCN).

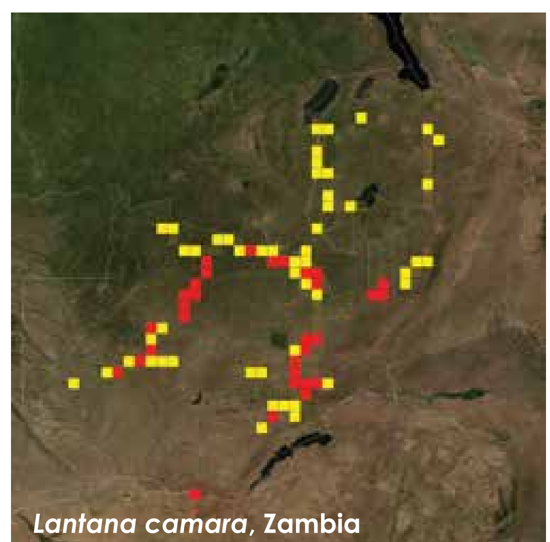
Papers, meanwhile, written by IAS scientists from the four participating African countries were submitted through the project for publication in international journals. Griffin Shanungu's study, *Management of the invasive* Mimosa pigra *L. in Lochinvar National Park, Zambia*, for example, was published in Biodiversity 10 (2&3), 2009 (pp. 51–56). Other papers appeared in local scientific publications, including – in the *Ethiopian Journal of Weed Management* – several IAS field studies from Ethiopia.

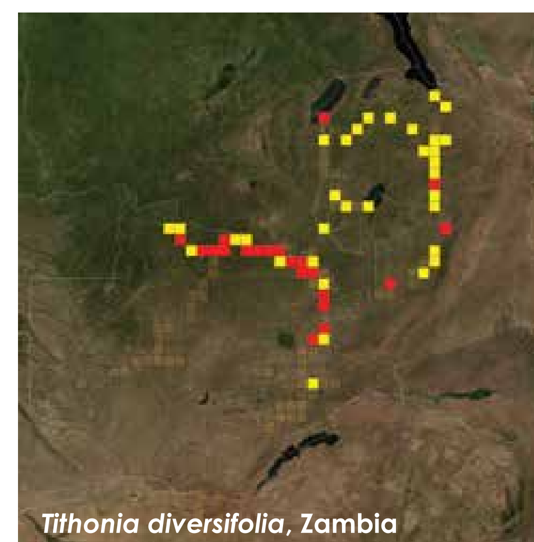
Outcome 3 – More effective IAS management practices

Outputs under this component of the project were all related to the implementation of effective and sustainable management actions and programmes, both for preventing the influx of invasive alien plant species and for controlling the spread of existing infestations.

To this end, IAS Risk Analysis procedures were to be developed for use by the quarantine authorities in each of the four countries. Systems of IAS monitoring (for Early Detection) and of Rapid Response were to be introduced. Environmental risk assessment procedures were to be incorporated into existing inspection regimens governing imported plants and plant materials. Ecosystem Management Plans, based on Environmental Impact







Distribution of selected invasive plant species, (not all regions in each country were surveyed). Key: Not present Present and/or naturalized Invasive.

Assessments carried out during the planning phases of the project and subsequently endorsed by stakeholders at pilot sites in each host nation, were to be implemented.

Integrated IAS control interventions, incorporating a range of targeted manual, mechanical, chemical and biological control methods, were to be applied at the pilot sites. Monitoring systems were to be established to track the benefits of the control interventions, both in terms of biodiversity indices and socio-economic gains.

▶ Risk Analysis

A review of the Risk Analysis procedures in place in each of the four participating nations had revealed a number of gaps and inconsistencies, particularly with respect to the assessment of prospective imports of plants and plant materials for potential environmental risk. The RBIPMA project was able, in most cases, to plug these gaps and to bring the national Risk Assessment procedures into line with the requirements of the International Plant Protection Convention (IPPC) – to which all four countries are signatories.

As a result, Risk Analysis procedures were strengthened considerably in Ethiopia, Uganda and Zambia. Uganda has for some time also been applying the methodology of the Australian Weed Risk Assessment (WRA) system – a model which has served the country well. Australia's WRA system, posted on the website of the Australian Quarantine Inspection Service (www.aqis.gov.au/docs/plpolicy/weeds1), is novel in that it uses a predictive points-scoring system based on responses to a questionnaire to evaluate and determine the potential invasiveness of would-be plant imports.

Some of the project's prescribed target indicators – including one stipulating that, within the time-frame of the project, there should be systems in place to ensure that approvals on no fewer than 80% of all legally imported new plants and plant materials be made subject to an Environmental Risk Analysis – proved unattainable and difficult even to quantify, given the huge numbers of border posts and crossings involved. Marked improvements in the enforcement of quarantine regulations were, however, achieved at most major entry points. Porous borders and unofficial cross-boundary traffic remain worryingly open and unguarded as pathways for the influx of invasive alien plant species into all four African countries.

▶ Early Detection and Rapid Response

Mechanisms for the Early Detection of, and Rapid Response to, new infestations of invasive alien plant species were developed in all four countries over the course of the RBIPMA project. Final guidelines for applying these mechanisms were agreed in Uganda and Zambia, but in Ethiopia and Ghana only draft guidelines were produced. The mechanisms – like so many others developed during the project – carry cost implications. So their full implementation will be possible only after the necessary cost-recovery mechanisms, developed under Outcome One of the project, become operational, or once national governments make long-term funding available for IAS management.

The Early Detection and Rapid Response systems already in place in some of the countries had been designed for the interception of agricultural crop pests only. So these mechanisms were expanded to include invasive alien plant species as well. The identification of invasive plant species, coupled with inadequate reporting systems, remains a major constraint, however, making the early detection of new alien plant invaders in the field hard to achieve, which in turn may preclude the likelihood of a sufficiently rapid response, even after the new mechanisms are fully implemented.

Parthenium infested pastureland in Ethiopia can no longer sustain any livestock ©Arne Witt

▶ IAS control interventions at pilot sites

The effectiveness of IAS control measures applied at infested pilot sites in the four nations was a particularly strong feature of the RBIPMA project. At most of the sites – there were nine pilot sites in all – integrated IAS interventions combining manual, mechanical, chemical and biological methods of control were used.

In some cases, extensive tracts of infested habitat were cleared of targeted plant invaders. In particular, removal of mature, seed-bearing plants helped to reduce the numbers of propagules, thereby slowing rates of spread within and around the pilot sites. Rehabilitative follow-up actions, based on sound ecosystem management plans, were initiated at some of the sites, to reduce the likelihood of habitat degradation and re-infestation. Monitoring indices for some of the IAS control interventions showed significant biodiversity gains.

In **Ethiopia**, Parthenium Weed and Prosopis were both cleared from hundreds of hectares of farmland and pasture on and around the Welenchiti and Amibara project sites. Control of both species in and around the Awash National Park, in particular, succeeded after three years in reducing the infestations by as much as 75%. Much improved crop yields were recorded in farming areas cleared of Parthenium, while on pasture rangelands forage productivity increased markedly following the removal of Prosopis, with the gradual return of previously suppressed native grasses. Detailed studies on the effectiveness of various control measures used in Ethiopia for Prosopis and Parthenium Weed were undertaken during the project, but the findings of these studies have yet to be published.

At a third site in Ethiopia, within the Awash River Catchment System, a Water Hyacinth infestation was cleared from feeder streams on the Wonji Sugar Estate, thus stopping the weed's spread into the Awash River.

The gains registered in Ethiopia were achieved largely through labour-intensive manual control methods, although some herbicides were also used. Ethiopia – alone among the four project nations – has, to date, never practised biological control. This may be about to change, however, as laboratory facilities, developed over the course of the project, will allow weevils (of the species already in use for controlling Water Hyacinth infestations in Uganda, Ghana and Zambia, as well as in other nations both on the African continent and elsewhere) to be mass-reared in Ethiopia. The weevils are to be imported, tested to confirm their host-specificity and then released just as soon as the necessary supporting legislation (which was drafted during the project) has been passed into law.

The introduction into Ethiopia of biological agents for controlling Parthenium is also imminent. Recourse to biocontrol is expected to reduce substantially the costs of IAS management programmes in Ethiopia. This is seen as a crucial step, if millions of hectares of formerly productive agricultural and pasture land, now overgrown with weeds, are to be rehabilitated.

Some ecological rehabilitation work was carried out in Ethiopia on sites cleared of Prosopis. Erratic rainfall, though, and limited water resources in these and other semi-arid zones meant it was difficult, within the time-frame of the project, to gauge the effectiveness of follow-up re-plantings with indigenous herbs and shrubs.

In **Ghana**, Paper Mulberry trees were cleared from selected demonstration plots collectively spanning about seven hectares (or roughly five percent) of the infested habitat in around the Afram Headwaters Forest Reserve. Monitoring of the cleared areas revealed a marked recovery among native plant species whose regeneration had previously been inhibited by the canopy of the mulberries and by their extensive lateral root systems. The biodiversity gains were closely studied, and all the resulting data, once this has been collated, will be published.

In farming areas outside the Reserve, trials were carried out on different methods of cultivation, aimed at enhancing yields by 'shading out' re-sprouting or coppicing mulberries. One method, involving the growing of cassava and of arrow-root plants more closely together and in more narrowly spaced rows was found to be especially promising. The findings of these experiments, once collated, are also to be published.

Existing biocontrol programmes in Ghana had been using *Neochetina* weevils to contain the spread of Water Hyacinth within the Oti Arm of Volta Lake. Efforts at this site were bolstered over the course of the project by the introduction and release – through Ghana's established biological control laboratories – of additional agents, in the form of a population of sap-sucking mirid insects of the species *Eccritotarsus catarinensis*. The mirids, which have proved highly effective in supplementing the effects of feeding damage caused by the weevils in many other regions, are expected to help the Ghanaian authorities to prevent the hyacinth from entering the main body of Volta Lake.

Here, as at other project sites where Water Hyacinth infestations were addressed, it was not possible – in any comprehensive sense, above and beyond the immediate benefits for some conspicuous benthic vertebrates – to monitor the biodiversity gains achieved through the integrated clearing and control interventions.


Water Hyacinth-infested canal on the Wonji-Shewa Sugar Estate, Ethiopia ©Arne Witt

In **Uganda**, Spectacular Cassia trees and their propagules were removed from some parts of the Budongo Forest. Trials aimed at optimising methods of controlling the area's Cassia infestations and at rehabilitating forest areas cleared of these trees were undertaken during the project, and are continuing.

At the Lake Mburo site in Uganda, meanwhile, steps were taken to intercept the spread of Water Hyacinth through the Ruizi River system, and so prevent the weed from entering Lake Mburo and other smaller lakes and wetlands in the Lake Mburo National Park. Biocontrol agents were re-distributed from other hyacinth-infested lakes and wetlands in Uganda, as part of a rapid response action aimed at reducing Water Hyacinth infestations in the Ruizi River catchments.

The invasive lemongrass, False Citronella, was cleared from a number of heavily infested areas of Mbarara District in and around Lake Mburo National Park. Trials using various control methods and combinations were conducted. Burning, followed by herbicidal treatment, was found to be the most cost-effective means of controlling False Citronella in Uganda. In the cleared areas, impressive biodiversity gains were recorded, along with significantly enhanced forage productivity. The immense scale of the invasion remains daunting, however, and calls for a massive escalation of the responsive actions refined and demonstrated during the project trials.

Some of the project's work in Uganda was directed towards helping communities combat the spread of *Lantana camara*. Although Lantana was not among the alien invaders singled out for attention in Uganda, its infestations are considered by many Ugandans to be an especially urgent management priority. So project personnel were repeatedly implored, during presentations, to include advice on managing Lantana as well. By popular demand then, the RBIPMA project was able to arrange a number of productive exchanges with the Zambian arm of the project, for which the control of Lantana was a designated priority.

In **Zambia**, 800 hectares of infested floodplain in the Lochinvar National Park were cleared of *Mimosa pigra* – the Giant Sensitive Plant. The clearing operation, carried out with assistance from the Government of Zambia, reduced the extent of Mimosa infestation within the Chunga Lagoon sector of the Park by roughly 30%. Before clearing began, a study funded by the project could find only 314 birds (of 24 species) in infested areas of the Park. In non-infested areas, by contrast, the survey's tally was 19,265 birds (of 46 species). The Chunga clearing operation, then, would have potentially enormous implications for the area's bird life and avian diversity.

After clearing, marked increases were

Manual control of Mesquite (*Prosopis juliflora*) in Ethiopia ©Rezene Fessehaie

recorded in the numbers of individual birds and animals present, and in the numbers of species represented. Among the returnees observed in cleared areas were the endangered Wattled Crane, *Grus carunculatus*, and several other bird species (mainly waders) which had not been seen in the area of infestation prior to clearing. The vulnerable endemic antelope subspecies, the Kafue Lechwe, *Kobus leche kafuensis*, was conspicuous among mammals seen returning to lagoon areas cleared of *Mimosa pigra*.

Rehabilitation of cleared areas in the Lochinvar National Park was not attempted, as the native floodplain vegetation, pre-invasion, consisted almost entirely of grasses, many of which had not been identified with certainty. The natural grass cover was in any case gradually returning; so deliberate re-planting was deemed unnecessary.

In the Mosi-oa-Tunya National Park, meanwhile, the project was instrumental in clearing *Lantana camara* from an area of about 30 hectares. This amounts, however, to little more than six percent of an infestation that, in all, is believed to extend over an area of roughly 524 hectares. Some of the invaded terrain – in the gorge below the Victoria Falls, especially – is precipitously steep, making access difficult, dangerous and in places impossible. Yet clearing teams, using a combination of uprooting and of cutting back and applying systemic herbicides, were able to remove some entire thickets of Lantana from stretches of riverbank above the falls and also from more accessible parts of the lower gorge.

In the cleared areas, seedlings of a variety of indigenous trees and shrubs, grown in nurseries set up on the compounds of local hotels and tourist establishments, were planted out, to supplement the natural regeneration of germinating seedlings within the soil's existing seed-bank. All rehabilitated 'plots' were very closely monitored, to gauge the rates of ecosystem recovery.

In the meantime, biocontrol agents, imported from South Africa under the terms of Zambia's Plant Quarantine and Phytosanitary Act, were bred up and acclimatised in special walk-in cages located at a nearby hotel. These agents included the leaf-mining beetle *Uroplata girardi*, which by feeding on the leaves of *Lantana camara* impairs the function of the shrubs, inhibiting their ability to produce flowers and fruits – thereby retarding their growth and slowing their spread. The beetles were subsequently released, and signs of their efficacy (including visibly damaged and discoloured Lantana bushes in some precipitous gorge areas of the Mosi-oa-Tunya National Park that are not accessible to humans) are now widely evident.

Zimbabwe's Victoria Falls World Heritage Site on the other side of the Zambezi River, in being contiguous with Mosi-oa-Tunya, shares many of the same problems – not least as regards the menacing spread of infestations of Lantana. So the project was able here, through the IUCN, to foster a collaborative trans-boundary control strategy, bringing together affected stakeholders (including conservation authorities and tourism and resource managers) from both nations.

On the Zambian side of the river, the project was able, moreover, to clear Water Hyacinth from infested stretches of the Maramba River, a tributary of the Zambezi that flows through the southern town of Livingstone. Control trials, using glyphosate foliar sprays, were conducted on one secluded stretch of slow-flowing water that had been heavily invaded. Breeding centres for biological control agents, in the form of the weevil species *Neochetina eichhorniae* and *N. bruchi*, were also established, and hundreds of these weevils were released in 2009, as part of a longer-term strategy for Water Hyacinth control on the Maramba.

This intervention, by slowing the spread of the floating weed into and along the Zambezi, is expected to benefit downstream riparian communities as far away as Mozambique, as well as in both Zambia and Zimbabwe.

TOP 20 INVASIVE ALIEN PLANTS

Ethiopia	**Ghana**	**Uganda**	**Zambia**
Acacia saligna	*Ageratum conyzoides*	*Ageratum conyzoides*	*Ageratum conyzoides*
Ageratum conyzoides	*Antigonon leptopus*	*Azolla filiculoides*	*Azolla filiculoides*
Argemone ochroleuca	*Azolla filiculoides*	*Broussonetia papyrifera*	*Canna indica*
Caesalpinia decapetala	*Azadirachta indica*	*Calliandra calothyrsus*	*Datura stramonium*
Cirsium vulgare	*Broussonetia papyrifera*	*Canna indica*	*Eichhornia crassipes*
Cryptostegia grandiflora	*Canna indica*	*Cardiospermum grandiflorum*	*Ipomoea carnea*
Datura stramonium	*Cercropia peltata*	*Chromolaena odorata*	*Ipomoea tricolor*
Eichhornia crassipes	*Cedrela odorata*	*Datura stramonium*	*Lantana camara*
Lantana camara	*Chromolaena odorata*	*Eichhornia crassipes*	*Melia azedarach*
Mimosa pigra	*Eichhornia crassipes*	*Lantana camara*	*Mimosa pigra*
Mimosa diplotricha	*Lantana camara*	*Mimosa pigra*	*Opuntia ficus-indica*
Nicotiana glauca	*Leucaena leucocephala*	*Parthenium hysterophorus*	*Pennisetum setaceum*
Opuntia ficus-indica	*Limnocharis flava*	*Pistia stratiotes*	*Pistia stratiotes*
Opuntia stricta	*Luffa cylindrica*	*Prosopis juliflora*	*Psidium guajava*
Parthenium hysterophorus	*Mimosa pigra*	*Senna hirsuta*	*Ricinus communis*
Pistia stratiotes	*Opuntia stricta*	*Senna occidentalis*	*Salvinia molesta*
Prosopis juliflora	*Parkinsonia aculeata*	*Senna spectabilis*	*Solanum seaforthianum*
Senna occidentalis	*Pistia stratiotes*	*Solanum mauritianum*	*Tithonia diversifolia*
Xanthium spinosum	*Salvinia molesta*	*Thevetia peruviana*	*Tithonia rotundifolia*
Xanthium strumarium	*Tithonia diversifolia*	*Tithonia diversifolia*	*Toona ciliata*

Outcome 4 – Enhanced capacity for IAS management

Outputs achieved under this component of the RBIPMA project included the training of stakeholders at all levels. Recipients included government policy-makers and legal practitioners, agricultural officers and support staff, plant quarantine supervisors and personnel and conservation and land- and resource-use managers and staff, as well as farmers' and pastoralist groups from vulnerable communities and game rangers and scouts working in conservation areas. The training programmes, suitably tailored in each case, covered all aspects of IAS and their management.

At the same time, IAS modules were assimilated into the coursework of technical training colleges and other academic institutions, including high schools, in each of the participating countries. Training manuals and management guidelines were freely distributed, along with other educational materials, including eye-catching pamphlets and posters. Field outings for parties of schoolchildren and their class teachers were arranged as part of the project's long-term awareness- and capacity-building mission.

Post-graduate research studies specialising in IAS were initiated, and the findings of some completed studies have since been published in international journals. The aim was to ensure that IAS knowledge and management acumen gained during the project would go on being sustained as part of the wherewithal of prospective future resource managers and administrators and their staff, through the work of on-the-job instructors and of teachers at educational establishments.

Trainees, meanwhile, were able – through the project – to participate in several regional and international forums on invasive plant species. At these conferences and workshops, some of which are listed above (under *Outcome 2*), the sharing of both information and experiences was instrumental in giving IAS trainees from different regions a broader understanding of the economics of IAS management, while also enabling them to play an active part in helping to formulate common guidelines and best practices for systems of cost-recovery, Risk Assessment and Early Detection and Rapid Response.

In **Ethiopia**, no fewer than 2,536 stakeholders received IAS training through the project. Of these, 401 trainees were the holders of senior posts in agriculture-related fields, including agricultural research; 20 were plant quarantine inspectors and staff; 184 were agricultural and development extension officers and supervisors; 41 were wildlife rangers and game scouts, and 1,890 were either farmers or pastoralists. All were given training materials, ranging from manuals in some cases to management guidelines issued in the form of brochures and other aids – including IAS calendars and posters specially printed in the major vernacular languages.

More than 40 Ethiopian university students were able meanwhile, over the course of the project, to complete post-graduate dissertations on aspects of locally occurring invasive alien plant species and their management.

In **Ghana**, 249 stakeholders attended IAS identification and management training workshops organised by the RBIPMA project. The Ghanaian trainees included 15 policy-makers; 50 plant quarantine and inspection personnel, and 184 representatives from farming and pastoralist communities.

IAS training modules, developed through the project, were incorporated into the curricula of all the country's agricultural training colleges, having been approved in a national curriculum review carried out during the project's implementation phase. An educational pack for Ghanaian schools was undergoing trials at two leading schools, and would – if adjudged to be successful – be 'rolled out' nation-wide, following the country's next official school curriculum review. A Ghanaian PhD thesis – by Felix Akpabey, on the socio-economic and environmental impacts of the Water Hyacinth and on the management of these impacts – was

Manual control of *Mimosa pigra* in Lochinvar National Park, Zambia ©Arne Witt submitted for review in June 2011. That doctorate has since been awarded (in April 2012).

In **Uganda**, more than 2,000 stakeholders from 30 districts attended the project's IAS training workshops in the country. The dissemination of training materials – in the form of brochures, posters and other aids – was especially successful in Uganda, where an assessment of levels of awareness, post-project, revealed an increase of as much as 70% across some whole districts. A 25-minute film, entitled *The Threat of Invasive Alien Species in Uganda*, shown on national television, as well as at many workshops and forums around the country (and further a-field), was particularly well received, and has done much to help inculcate IAS awareness.

Two IAS teaching modules, developed through the project, were integrated into the curricula of agricultural colleges in Uganda. The educational packages prepared for Ugandan schools were (as in some of the other project countries) awaiting formal approval under the next national school curriculum review. A Ugandan post-graduate student, Peter Beine, received an MSc degree for his important study on the socio-economic and environmental impacts in Uganda of the invasive Spectacular Cassia, *Senna spectabilis*.

In **Zambia**, the involvement of schoolchildren and their teachers in IAS activities was a particularly strong feature of the project. In 2009, on International Biodiversity Day (22 May), for example, the project – in association with both the Wildlife and Environmental Conservation Society of Zambia and the then-Environmental Council of Zambia – organised a day-long inter-schools IAS Quiz and field outing held at the Maramba River Lodge, near Livingstone.

In all, more than 450 pupils from ten different schools took part in the event, in the course of which a 600-m² expanse of infested riverbank was cleared of Lantana. The event culminated in a march-past from Mosi-oa-Tunya to Livingstone. On the march, the children – all wearing special T-shirts they had been given, emblazoned with messages drawing attention to the IAS cause – were joined by scores of other local community stakeholders and enthusiastic bystanders.

Elsewhere in Zambia, 18 legal practitioners and 17 plant import inspectors and quarantine officers attended intensive training workshops and seminars dedicated to Risk Assessment, Early Detection and Rapid Response. Two post-graduate Zambian students, Michael Nangalelwa and Brian Nkandu, meanwhile, were able to complete their MSc studies, on managing the impacts of *Lantana camara* and *Mimosa pigra* respectively. As in Uganda, a marked increase in national IAS awareness was found to have occurred in Zambia as a result of the project. IAS educational packs continue to be widely distributed among Zambian schools and learning institutions.

Ongoing appraisals

Comprehensive Project Implementation Reviews (PIRs), commissioned annually by the Global Environment Facility (GEF) to monitor the project's progress year-on-year, assigned performance ratings to all four of the project's targeted outcomes and to each one of the 35 envisaged contributing outputs and its associated actions.

Annual progress towards meeting the prescribed indicators set for each desired output was evaluated in accordance with the six-point rating system employed by the GEF. Under this system, performance is ranked on a scale that includes the grades: Highly Satisfactory (HS), Satisfactory (S), Marginally Satisfactory (MS), Marginally Unsatisfactory (MU), Unsatisfactory (U), and Highly Unsatisfactory (HU).

In the event, most of the outputs of the RBIPMA project were accorded annual ratings of HS, S, or MS. Performance ratings were further broken down to reflect the relative degrees of success attained each year in each individual nation. So, whereas a particular output may have warranted an HS rating in one country, or for one year, in another a performance rating of no better than MS, or even MU, could be achieved for the same output. For none of the project outputs was an HU grade registered over any one year, although in some cases – assessed as U – the prescribed indicators used were found in retrospect to have been unrealistic, overly ambitious, or otherwise at fault, according to the annual PIR assessment.

In general, the RBIPMA project was found to have been most successful (HS) year after year in the areas of generating awareness and of building IAS management capacity, as well as in actions taken at pilot sites in the field within each of the four nations. Question marks remain, however, over the long-term sustainability in some of the countries of certain aspects of IAS policy and institutional reform introduced over the course of the project. While work is continuing towards achieving outputs of this kind that have yet to be fully realised, some of the national executing agencies and their apex bodies are being hampered through having little direct influence over the workings of the broader political process.

'Loose-ends' notwithstanding, the RBIPMA project has succeeded in creating, in all four African countries, a solid platform on which to build a lasting response to the menacing impacts of invasive alien plant species and their spread. Significantly, each country is now far better placed to meet the strategic biodiversity goals set out under Article 8(h) of the Convention on Biological Diversity (CBD).

As such, the project's immediate objective or purpose has largely been met, and its four targeted outcomes have been achieved. The enabling policy and cross-sector institutional wherewithal for preventive action and responsive IAS management have been strengthened. Information on IAS risks, impacts and management interventions is now available in each of the participating nations, even if this information has yet to be fully utilised by all major stakeholder groups. Awareness levels have increased markedly, and comprehensive IAS management strategies – albeit yet to be applied nationally, in most cases – are now in place. Cross-sector IAS management capacity, although always at a premium, has also been significantly enhanced.

An independent Terminal Project Review, commissioned by UNEP in 2012, assessed the legacy and the long-term sustainability of all project outcomes in each host country.

Lessons arising from the experiences of the RBIPMA project have potentially enormous implications for the shaping and implementation, elsewhere in Africa and around the world, of forthcoming IAS projects and programmes – as we shall see in the following chapter …

Taking stock

Lessons learned and recommendations arising from the experiences of the project

The Removing Barriers to Invasive Plant Management in Africa (RBIPMA) project stands out as one of the most wide-ranging and ambitious campaigns yet undertaken in the global effort to 'scale up' the fight against damaging impacts arising from the spread of invasive alien species. As such, the results of this UNEP/GEF campaign, waged over a period of more than four years, are seen as enormously instructive in terms of shedding light on how best to go about mounting future IAS campaigns – both in Africa and elsewhere in the developing world.

The results of the RBIPMA project are to be published in full and disseminated upon completion of a UNEP-commissioned Terminal Project Review. The Review is to be carried out by a team of independent consultants in mid-2012 – exactly one year after finalisation of the project's extended implementation phase. The detailed Review, to be posted on **www.unep.org/eou/ReportsandPublications/ProjectEvaluationReportsandCommentaries/tabid/2315/Default.aspx**, will examine and assess the status, going forward, of all ongoing programmes and activities initiated through the project in each of the participating African countries – Ethiopia, Ghana, Uganda, and Zambia. This evaluation exercise will provide valuable insights into the practical legacy and likely future sustainability of all project outcomes.

Lessons learned over the course of the RBIPMA project have meanwhile already been applied to other similar GEF-funded invasive alien species' projects in South East Asia, the Caribbean and elsewhere. Some of the more important lessons are summarised in this chapter …

Lesson one:

It takes time to establish and to institute effective IAS management programmes in developing countries that have little or no prior awareness of the need for, or which lack the capacity to implement, such programmes.

That there are limits to what lasting outcomes can realistically be achieved within a developing country over the four- or five-year time-frame of a single project is one of the major lessons to have emerged from the RBIPMA experience. An IAS project, then, undertaken in such a country, should not be overly ambitious, or spread itself too thinly. Instead, it should prioritise and focus on entrenching a core framework of programmes and measures that in practice can be sustained. More time may then be needed to consolidate, build on and extend these core operations, once established.

In retrospect, the RBIPMA project – by its own admission – "set out to do too much". Partly, this was because the project had underestimated the length of time that would be needed to accomplish certain designated goals. Some of the indicators, meanwhile, that were used to define and to measure the effects of desired individual outputs on overall outcomes in some of the countries were, in retrospect, somewhat unrealistic, meaning in some instances that time and resources invested in the pursuit of "difficult" (and sometimes comparatively minor) goals detracted from the focus on delivering other, more important 'core' outputs.

So, while the project succeeded, in each of the participating African countries, in meeting, or even in exceeding, the targets set out under most of its indicators, not all of these successes have added up to coordinated IAS management outcomes that will be sustainable in the longer term.

In particular, the RBIPMA project underestimated the long start-up times that are needed in Africa to get a range of undertakings of this magnitude off the ground. Despite the extensive groundwork carried out beforehand, during the planning phases of the project, implementation in some of the countries did not begin in earnest until more than one year into the active project cycle.

The project also underestimated the amount of time that would be needed to bring about some of the necessary legislative and policy changes. The passing of any new legislation, by Act of Parliament, can take far longer than the project had anticipated. This meant that, in some countries, ratification of the new National Invasive Species Strategy and Action Plans (or NISSAPs) was not possible during the project's active implementation phase. Similarly, incorporation of the national 'apex bodies' set up to coordinate IAS policy and management was not always feasible within the initial four-year RBIPMA implementation period. In most of the countries, major policy reviews, of the kind needed in order to amend a National Biodiversity Strategy and Action Plan (NBSAP), are conducted only at five-yearly intervals. The same goes for other policy reviews, relating for example to integration of IAS instruction modules, developed during the project, into the formal curricula of a country's schools and technical training colleges.

This in turn meant, in some cases, that other instruments – dependent on the passage of new or of amended legislation or policy – had to be deferred as well. Some of the cost-recovery mechanisms developed through the project, for example, could not be implemented as planned, during the life-time of the project, because the introduction of such measures, while agreed upon, had yet to be formally sanctioned in law.

The sequential nature of so many of the targeted RBIPMA project outputs was, in retrospect, not adequately catered for. All too often, the successful delivery of one project output would depend on first meeting the goals of another output or activity. There were limits, in other words, to how much could be accomplished in parallel, as had been envisaged, over one and the same time period.

The major lesson to be drawn from this is that future IAS projects in Africa need to be conceived as part of a longer-term programme, undertaken in at least two – and possibly even three – strategic phases. The first such phase might then be dedicated to establishing all the necessary enabling conditions, such as awareness, national IAS inventories, and impact cost assessments. The setting up of management instruments, including systems of Risk Assessment and cost-recovery, could then be undertaken during a second phase.

Lesson two:

First-time IAS projects undertaken in developing countries may have very little by way of baseline information to work from on a country's invasive species and their distributions and impacts.

Within most developing countries, there is very little pre-existing baseline data on the occurrence or the distribution or impacts of invasive alien plant species. So, any project setting out to promote IAS awareness and develop IAS management capacity in such a country must first establish what invasive species occur, where they occur, how fast they are spreading (or are likely to spread), which invasive species are most damaging, and what their major impacts are.

Gathering this information takes time, and calls for well-developed identification and assessment skills – skills which, more often than not, are lacking in the countries concerned. In retrospect, the expectations of the RBIPMA project, in setting out to compile comprehensive IAS databases together with IAS distribution maps for entire countries, was overly ambitious – at least within the time-frame of the project. The logistics of carrying out nation-wide surveys are such that, realistically, depending on a country's size, two years or more may be needed to complete such comprehensive surveys. Enormous additional resources would also be needed. Not surprisingly then, the

RBIPMA project was forced into scaling down some of its initial expectations and into focusing instead on compiling select inventories of only the most damaging invasive plant species.

The encouraging news is that, in some of the participating African nations, work towards expanding the IAS inventories is continuing. Over the course of the project's implementation phase, however, certain other outputs, dependent on this information, such as the IAS databases and distribution maps intended for posting on each of the national IAS websites, were unavoidably delayed.

On current IAS projects, under way in South East Asia and elsewhere, efforts have been made to get around some of these problems by focusing instead on gathering precise information on particular infested areas, rather on trying to build up comprehensive databases for whole countries. More emphasis is also being placed on the sharing of information on invasive plant species that are a common threat in multiple countries through a single regional database, rather than on trying to include information on all possible invasive alien species on a separate website for each one of the IAS-afflicted nations. A Regional IAS Identification Guide is also being developed for South East Asia, as this is a tool which – in retrospect – is felt to have been missing from the resource base provided by the RBIPMA project.

Weeds have a dramatic impact on crop production, reducing yields by up to 30% in developing countries – in Africa, weeding is a task mainly undertaken by women and children ©George Oduor

Another envisaged output that, in Africa, proved overly ambitious, and altogether impossible to verify, was the stipulation to the effect that by the time the project had run its course at least 80% of all new imports of plants or plant propagules into each host country would be subject to routine environmental risk assessment. This was a flawed and unrealistic target, given the huge numbers of border posts and crossings involved, not to mention the porous nature of most international boundaries.

Performance in relation to other RBIPMA prescribed targets was often difficult to assess, for want of adequate provision (in terms of time, expertise, and resources) for the application of scientific methods of, and criteria for, monitoring and evaluation. The requirement, for example, that the rate of spread of targeted invasive species at pilot sites be reduced by 80% within four years was impossible to gauge accurately over such a limited period of time. Likewise, it was not easy to assess, in percentage terms, recovery rates for local biodiversity. Increases in prevailing levels of popular IAS awareness, too, were hard to measure precisely, on the basis of what amounted in the end to little more than a series of improvised random surveys.

The need for more professional monitoring and evaluation techniques for gauging the effectiveness of actions and interventions emerged as one of the principal lessons of the project. Indeed, a dedicated M&E (Monitoring and Evaluation) Component is now an integral part of other IAS projects embarked upon subsequently elsewhere in the world.

Lesson three:

Eliciting the commitment, early on, of politicians and of policy-makers at the highest level is usually essential to the genesis and long-term success of national IAS management programmes.

In developing nations, both in Africa and elsewhere, it is often quite easy to elicit active support for IAS-related activities from among rural communities. It is the rural communities, after all, which have to bear the brunt of the destructive impacts meted out by invasive species. So awareness at the community level is in most cases easily cultivated and channelled into practical actions on the ground. Most aspects, though, of effective and sustainable IAS management also require resources, which of course the rural communities do not have.

The centralised structure and function of most African governments, moreover, is such that even revenues generated by state institutions at the sub-national level – by protected areas, say – are first allocated to a central fund, from which disbursements for management activities are re-distributed. The role of decision-makers in central government is very often pivotal, then, in determining the funding allocations of both rural communities and national parks and reserves.

Securing funding for the management of invasive alien plant species in particular can be difficult, given the welter of competing priorities facing most governments in Africa. Accordingly, the development of IAS cost-recovery mechanisms, designed to relieve the burden on central government coffers, was one of the central aims of the RBIPMA project. Yet in most instances such mechanisms cannot be activated until legislative changes are effected, which again requires central government approval.

The challenge then becomes one of how these same over-stretched governments can be persuaded to prioritise the passing of the required legislation, along with new bills ratifying other enabling IAS instruments, such as the National Invasive Species Strategy and Action Plan (NISSAP) or the ‘apex body’ through which to coordinate IAS management nationally.

During the planning stages of the RBIPMA project, a lot of emphasis was placed on working with and nurturing IAS awareness among policy-makers and members of parliament from different government ministries. In reality, however, this was never easy, particularly given the need to arrive at a consensus, across sectors, involving several different ministries and parastatal authorities. It soon became apparent, too,

Field day in Ethiopia – creating awareness as to the threats posed by Parthenium Weed, ©Arne Witt

that the machinations of government varied markedly from one country to another. This meant there was no 'one-approach-suits-all' strategy for inculcating government awareness and generating the political will to act. That different political awareness strategies may have to be adopted in different countries is a lesson that future multi-country IAS projects in Africa will have to bear in mind.

Lower down, at the provincial or the county level, the frequent 'rotation' in some countries of local government officials is another factor that, in the experience of the RBIPMA project, can disrupt the continuity of some IAS project activities. 'Bottom-up' lobbying on the part of rural communities, meanwhile, was often not successful either, in terms of garnering government support.

The political will of governments can be hugely influential, then, in determining the fortunes of IAS projects in Africa. Measures that are sorely needed to address the IAS threat are not always easily 'sold' to politicians, however, which means that, in the planning phases of a project, more thought should be put into how best to present and to argue the case for effective IAS management.

Lesson four:

The need for preventive IAS management is particularly hard to 'sell' in Africa, where in addition the implications of long-term biodiversity impacts, as opposed to immediate socio-economic impacts, are often relatively poorly understood by communities and governments.

The immediate concern in Africa, among politicians and local communities alike, is over getting rid of existing invasive plant infestations that are a direct and obvious cause of persistent human suffering and economic hardship. The RBIPMA control interventions at infested pilot sites on community lands in each of the four hosting nations were therefore extremely popular – and rapidly became the perceived central focus of the project as a whole.

This enthusiastic reaction is understandable in that the clearing of plant invaders from large tracts of infested habitat was of course the most dramatically conspicuous and tangible of all the project's outputs. The success of the control interventions was certainly helpful, too, in drawing public attention to the project and to the IAS threat more generally. At the same time, however, the purpose of the control interventions was widely misconstrued, creating the misguided impression in some quarters that the project was just an opportune vehicle for clearing invasive plant infestations that had been troubling people for many years.

In reality, such control interventions in themselves contribute very little to overall sustainability. Their purpose is simply to demonstrate best management practices that can go on to be applied, on an ongoing basis, by the countries themselves. Where this does not happen, or where no follow-up actions are taken, the cleared areas will soon be re-invaded – in which case all the effort and expenditure incurred in removing the plant invaders from the demonstration plots will have been largely wasteful.

Very much harder to convey to people is the need for pre-emptive measures to be instituted to prevent potential future invasions. The idea that an invasive species not present already in a country, or present only in certain localities and at low densities, might also become a serious and costly environmental or socio-economic hazard can be difficult for people to visualise, even with the help of eco-climatic modelling aids and other predictive data pointing to the likelihood of a full-blown invasion.

Benefit–cost analyses, extrapolated from other regions where environmental and climatic conditions are similar, and which show the disastrous economic and social consequences of preventive inaction, are very often not taken seriously – until it is too late. Investment in preventive mechanisms and in systems of Early Detection and Rapid Response is nevertheless frequently deferred.

The link between biodiversity protection and the broader socio-economic welfare of human societies is another factor that remains poorly understood in many parts of Africa. Biodiversity losses brought about by invasive species' infestations in national parks and national reserves are of little concern to some neighbouring communities, which instead are mindful only of their desire for immediate and tangible relief from all the misery and hardship they and their families are experiencing as a result of the ravages of invasive alien plants. Often, the communities do not appreciate the extent to which they depend on the health of protected natural ecosystems for many of their essential requirements – of water, for example.

Food securty in Africa is threatened by invasive species ©Patricia Neenan

The need for greater emphasis on effective social marketing of benefits accruing from biodiversity conservation and preventive IAS management, then, is yet another of the major lessons to have emerged from the RBIPMA project.

In particular, there is a need in Africa for 'bridging' initiatives linking the pursuit of socio-economic *and* biodiversity goals in relation to combating the introduction and spread of invasive plant species. The success of the South African Working for Water Programme has shown, for example, how poverty alleviation and job creation among poor communities can be the drivers of a hugely effective and sustained IAS management programme yielding significant biodiversity gains.

Emulating the social aspects of that programme was of course well beyond the scope of the RBIPMA project, which was – and is – essentially a biodiversity-driven undertaking. Yet on forthcoming GEF-funded IAS projects, partnerships entered into with other organisations that are active in social and community service may help to strengthen links between socio-economic and biodiversity-related project goals. Such partnerships are seen as vital in extending the reach and bolstering the effectiveness and long-term sustainability of IAS projects in the developing world.

LESSON FIVE:

In view of the immense scale of the problem and the continuing lack of available resources in most developing African countries, much more emphasis needs to be placed on cost-effective management practices, such as biological control.

There is an immense and growing gulf, in sub-Saharan Africa as in many other regions of the developing world, between the scale of existing IAS infestations (and of the enormous suffering these infestations are causing) and the resources that can be mobilised by individual countries to combat the invasions and their impacts.

Even developed nations with effective and well-established bio-security systems, and with cost-recovery mechanisms in place to help finance those systems, still have to rely to a large extent on direct government funding for the control of infestations of invasive alien plant species. In Africa, where cost-recovery mechanisms (such as those developed during the RBIPMA project) have yet to become fully functional, the financial burden of IAS control is simply too great for any central government to bear.

The costs of sustained mechanical and chemical control, while actively promoted during the project as essential aspects of integrated IAS management practice, are also prohibitive in many nations, particularly given the scale of the interventions that are required in cases where hundreds of thousands of hectares have already been invaded. This means that only the most cost-effective IAS control options are likely to stand any chance of real success in sub-Saharan Africa, if progress is to be made over the coming years in the battle to keep invasive plants and their impacts at bay.

To this end, IAS control programmes in Africa are going to have to make greater use of biological control (biocontrol). Not only are biocontrol programmes relatively economical, given that many biological control agents of proven efficacy and safety are already available and can be introduced at minimal cost; such programmes also ensure that a country's expenditure on other IAS control interventions, based on manual, mechanical, or chemical methods, can be substantially reduced. A biocontrol programme, moreover, once implemented, is permanent – and it incurs no associated running costs. So, for the control of very extensive infestations in countries that are strapped for resources, biological control may in many cases be the only realistic long-term management approach.

Wetlands and floodplains in Africa are threatened by a host of aquatic and semi-aquatic invasive plants ©istockimages

Lesson six:

The enormity and the growing severity of the IAS problem is such that nothing short of a concerted global campaign – eliciting massive long-term commitment and funding from all major donor nations, international development and aid agencies and NGOs – is needed, if this scourge is to be brought under control.

The RBIPMA experience has shown how even a modest donor-funded project can provide developing countries with a foundation on which to build effective IAS management programmes. The scale of the IAS problem and of the ecological, social and economic devastation it is causing around the world is such, however, that far greater levels of commitment and funding are required.

There is still a tendency, among donors and global development and aid agencies, either to ignore the problem or to underestimate the extent to which it is responsible for so much of the poverty and suffering that is so widely decried. What is needed, to help galvanise awareness and spur action, is a concerted global marketing campaign along the lines of the hugely successful campaign that was waged in the early 1980s drawing attention to the scourge of HIV/Aids. The critical mass generated by such a campaign might ensure that IAS issues are incorporated, as they should be, as one of the central components in all donor-funded development programmes.

The reach of the UNEP/GEF RBIPMA project, as we have seen, extended well beyond considerations of biodiversity alone. The justification for such a project and its funding cannot therefore be considered only within a framework of biodiversity- and conservation-related approaches and goals. Indeed, one of the recommendations arising from the experiences of the RBIPMA project is that future GEF-funded IAS projects should be treated from the outset, not just as biodiversity projects, but as Multi-Focal Area undertakings, providing for and making funding available as well for tackling the broader social and economic dimensions of the IAS problem.

Acacia tortilis is utilized extensively by communities living in East Africa ©Arne Witt

The way forward

RBIPMA International Project Coordinator, Dr Arne Witt, considers the outlook, post-project, for invasive plant management in Africa

Invasive alien plant species will continue, throughout Africa, to have dramatic and far-reaching adverse effects on human livelihoods. On a continent where small-scale farmers who depend for their survival on natural resources make up more than 80% of most national populations, these impacts are particularly severe. The agricultural labour force (as a percentage of the total labour force) in countries such as Angola, Zambia, Malawi, Mozambique, Uganda, Ethiopia and Sudan stands at between 80% and 90%.

Around the world, it is estimated that weeds, most of them introduced, are the cause of average crop-yield losses ranging from 25% in least developed countries to 10% in less developed countries. Of the 49 countries on the planet with least developed country (LDC) status, 33 are in Africa. This means that more than half of all the nations on the continent are, year after year, losing as much as 25% of their potential crop yields as a result of the presence of weeds alone.

These losses have continued, despite the fact that farming communities in Africa spend an inordinate amount of their time weeding. Indeed, hand-weeding – an activity performed mainly by women and children – accounts for as much as 60% of all pre-harvest labour. Studies have shown that about 69% of African farm children aged 5–14 are involved in agricultural endeavour, of which the core activity is weeding.

At the same time, invasive plant species are displacing native plants on which some entire communities of rural people depend. In the Turkana region of Kenya, where invasive *Prosopis* species are displacing indigenous plants, a recent study has shown that, of 113 woody species assessed, 85% (96 species) are of domestic or pastoral use. Documented uses include palm leaves for thatching, wood for charcoal production, edible fruits, livestock browse, medicinal extracts, materials for making traditional stools and head-rests, shade provision, resins that serve as glue substitutes, and even flowers picked for decorative purposes.

Here, as in other parts of East Africa, *Acacia tortilis*, for example, is an important provider of energy, food, browse, building materials, utensils, and both veterinary and human medicine, while also being used for religious and/or cultural purposes. The flowers are the primary source of high quality honey in many regions, while the pods (following extraction of the seeds) are used for making porridge. The Maasai eat the immature seeds. The leaves, bark, seeds, and the reddish gum of this species all have medicinal properties. Indeed, two pharmacologically active compounds, isolated from *Acacia tortilis* bark, have found applications in the treatment of asthma.

Pastoralism or livestock farming – an economic activity practised by millions of people on the continent – is today also under threat. A recent study in South Africa found that more than 70% of that country's natural grazing pasture might be lost if invasive plant infestations are not managed.

Wetlands throughout Africa, meanwhile, are under threat from a host of invasive plant species. Millions of people on the continent depend on wetlands for a supply of drinking water and food, as well as for irrigation and other services and economic resources (including raw materials for building and natural products and medicines derived from native riparian plants). In southern Africa's Zambezi River Basin, for example, annual economic values assigned to wetland resources include, among other benefits, US$ 50 million in floodplain recession agriculture, US$ 78.6 million in fish production, US$ 70.6 million in grazing for livestock, and US$ 2.6 million in natural products and medicines. The socio-economic repercussions, then, of continuing water depletion and of displacement of native wetland vegetation by invasive plant species is potentially nothing short of catastrophic.

The loss of native medicinal plants, in particular, is having dire consequences for rural communities around the world. Rural populations depend on such plants for as much as 80% of their primary health care needs. Many communities have no access to Western pharmaceuticals, which in any case are unfamiliar and often prohibitively expensive. This is particularly true of many African countries, where there are still comparatively few university-trained doctors. In Tanzania for example, which boasts fewer than 1,000 trained medical doctors, there are 30,000–40,000 practitioners of traditional healing.

The trade in medicinal plants contributes substantially, moreover, to livelihoods and income generation on the continent. In South Africa, trade in 771 medicinal plant species provides employment for no fewer than 133,000 people. There, the market for traditional medicines, numbering some 27 million consumers, is worth the equivalent of about US$ 340 million a year. So the contribution of native plant species to rural economies in Africa cannot be underestimated.

In the face of growing human suffering and economic hardship, the immediate detrimental impacts of invasive plant infestations are becoming increasingly apparent over much of Africa. Less well understood, however, is the link between biodiversity protection and conservation more generally and the broader social and economic welfare of communities. The function of healthy ecosystems in Protected Areas, in particular, is critical in underpinning healthy lives and productive livelihoods.

Biodiversity also contributes to the welfare of communities through creating job opportunities and other sources of revenue through tourism. Although poor countries in Africa command only a small share of the international tourism market, tourism can contribute significantly to the well-being of national economies.

Increasingly, the biodiversity encapsulated in many of Africa's Protected Areas is under threat from invasive plant species such as Parthenium Weed, Prosopis, Lantana, Chromolaena, and Giant Sensitive Plant, among others. Savannah ecosystems on which the bulk of the revenues derived from international tourism to Africa depend have in many cases already been invaded. *Lantana camara* is present in almost every Protected Area in southern and eastern Africa, while *Chromolaena odorata* has invaded large tracts of land in southern, central and West Africa, including National Parks and Reserves. *Prosopis* species have already invaded, or else are threatening to invade, Protected Areas in Uganda, Kenya and Ethiopia, as well as the vast Kgalagadi Trans-frontier Park straddling the border between Botswana and South Africa.

Introduced species of *Opuntia* cacti are ubiquitous in many of these Protected Areas. In Kenya, the Tsavo East National Park has been invaded by *O. stricta*, which occupies more than 2,500 hectares of terrain along the park's south-eastern boundary, and which is spreading in adjacent areas as well. The same species has invaded more than 40,000 hectares of the Kruger National Park in South Africa. Parthenium Weed has invaded the Awash and Nechesar National Parks in Ethiopia, the Queen Elizabeth National Park in Uganda, the Kruger National Park, and both the Nairobi National Park and the Masai Mara National Reserve in Kenya. The latter has also been invaded by *Tithonia diversifolia*, which is spreading rapidly throughout Africa.

The Giant Sensitive Plant, *Mimosa pigra*, meanwhile, has become established on floodplains and in wetlands and river systems in the Murchison Falls National Park in Uganda, the Gorongoza National Park in Mozambique, the Lochinvar National Park in Zambia, and in a number of other critically important wetland areas and floodplain ecosystems elsewhere on the continent.

Surveys carried out in South Africa's Kruger National Park have uncovered a total of 370 exotic plant species, growing mostly in the gardens and staff quarters of tourist camps and lodges. Of these, 121 are considered to be invasive species. Unfortunately, no similarly comprehensive surveys have been undertaken within Protected Areas in other parts of Africa. The result is that, in most of Africa's Protected Areas, very little is known about the nature or the scale of the invasive alien species' threat.

Existing scientific knowledge and information on invasive alien plant species and their distribution and impacts stems largely from research carried out in the developed world. With the notable exception of South Africa, developing nations in Africa and Asia are poorly represented in, and as focal points for, the IAS research effort. The result is that the scale and the severity of the IAS threat in Africa and elsewhere in the developing world goes largely unreported and is often grossly underestimated.

A recent literature review found that only 15.8% of all published papers on exotic species in relation to ecology and biodiversity had authors from developing countries and that only 6.5% had authors solely from developing nations. Clearly, this under-representation – and the resulting paucity of information – is a factor in preventing developing countries from devising and pursuing effective IAS management plans.

Mexican sunflower (*Tithonia diversifolia*) is spreading rapidly throughout tropical and sub-tropical Africa, already dominating many landscapes ©Arne Witt

The lack of data is compounded, in most developing nations, by a generally weak policy and institutional environment, by a continuing lack of awareness and of the capacity needed to identify and to manage invasive plant species, and by inadequate resources. Country Reports submitted over recent years to the global Convention on Biological Diversity (CBD) have shown consistently that these issues are generic, not just in Africa, but across much of the developing world.

In addition, there is a tendency, still widespread in Africa, to ascribe some useful properties to even the most highly invasive and damaging alien plant species. These are known as 'conflict species'. Their perceived benefits are often unsubstantiated. Often, such perceptions are based on arguments once perpetuated by international development agencies, but which (in the Western world at least) have long since been discredited. The persistence of positive attitudes towards some particularly menacing alien plant invaders continues to hamper implementation, in many African countries, of much-needed IAS management interventions and strategies. For example, no fewer than 72% of the exotic shrubs and trees described in the reference work, *Useful Trees and Shrubs for Kenya*, as being either "useful" or "beneficial" are listed elsewhere in the world as noxious environmental weeds.

The continued promotion, in many parts of Africa, of alien plant species that are known to be highly invasive is extremely worrying, and is considered by some to be criminal. Only where a plant invader is limited in distribution and is present in very low densities are communities of people anywhere likely to benefit. An invasive plant species will, by definition, quickly begin to spread, forming ever denser stands, while at the same time displacing useful native species. Any benefits the invader might once have provided will soon be outweighed by the increasingly destructive consequences of its spread. It is irresponsible, therefore, to consider the "beneficial" aspects of an alien plant invader in isolation.

Any assessment of benefits and costs that is not based on a scientific Ecosystem Approach is fundamentally, often tragically, flawed. The active promotion of invasive alien species also violates one of the basic tenets of sustainable development; namely that, *Development should meet the needs of the present without compromising the ability of future generations to meet their needs*.

Where an invasive plant species has been adopted by a community, it can be very difficult to persuade that community to consider other more benign alternatives. For example, invasive species such as *Lantana camara*, Mauritius Thorn (*Caesalpinia decapetala*), various Prickly Pears (*Opuntia* spp.) and other cacti species, the Mexican Sunflower (*Tithonia diversifolia*), the Creeping Sensitive Plant (*Mimosa diplotricha*), Yellow Oleander (*Thevetia peruviana*), and the Angel's Trumpet Tree (*Brugmansia suaveolens*) are all still widely grown in Africa as hedging or ornamental plants. For want of benign alternatives, removal of the hedges to stop the further spread of such plants meets with opposition from communities, many of which nevertheless freely acknowledge the problematic nature of the species in question.

Yet, while awareness of the invasive species' threat is undoubtedly increasing, a lack of resources and a plethora of competing priorities have meant, and will continue to mean, that governments across Africa are unlikely in any case to be able to finance large-scale clearing operations. Expecting people, even at the local community level, to contribute to the management of an invasive species is seldom realistic, when you consider that, on average, poor families living in rural communities in the developing nations of sub-Saharan Africa are spending 65–80% of their incomes on food, while passing most of their daily working hours tending their crops, collecting firewood and water, or taking care of their cattle.

The massive scale, both existing and potential, of invasive alien plant infestations in sub-Saharan Africa, moreover, makes a mockery of limited, or intermittent, control interventions. The immediate answer may lie in a more cost-effective and long-term approach, based on a technology that – so far, anyway, other than in South Africa – has not been widely embraced on the African continent. That technology is of course biological control, or biocontrol.

South Africa, now recognised as a world leader in biocontrol research, has to date released 106 biocontrol agents for the management of more than 50 invasive plant species. Many of these are species that are also problematic in other parts Africa, but against which biocontrol technology has so far not been deployed. Indeed, only about a dozen biocontrol agents have been released on the African mainland outside South Africa, and most of these organisms have been introduced for the control of aquatic weeds. This is surprising in view of the proven efficacy and safety of some of South Africa's established biocontrol programmes targeting terrestrial invasive alien plant species.

In South Africa, biocontrol programme research has revealed benefit–cost ratios ranging from 34:1 for Lantana to 4,331:1 for the Golden Wattle (*Acacia pycnantha*). Biocontrol has been found, moreover, to have reduced the country's expenditure on ongoing manual, mechanical and chemical control interventions by as much as 20% – representing an overall saving to date amounting to the equivalent of roughly US$ 165 million. Biocontrol programmes, if fully implemented in the future, are expected to result in further savings – of as much as 41.4% – in overall IAS control costs.

The host-specificity and safety of biological agents now being used effectively in the field has already been verified scientifically. So these tried-and-tested agents can be introduced elsewhere in Africa at a fraction of the cost that was incurred initially in research screening prior to release. Some of the agents released in South Africa and in Australia have been proved highly effective in controlling infestations of *Lantana camara*, *Chromolaena odorata*, *Parthenium hysterophorus*, *Mimosa pigra*, Creeping Sensitive Plant (*Mimosa diplotricha*), various *Opuntia* and other cacti species (such as *Cereus jamacaru*), Bug Weed (*Solanum mauritanium*), Madeira Vine (*Anredera cordifolia*), Cat's Claw Creeper (*Macfadyena unguis-cati*), *Cryptostegia grandiflora*, *Cirsium vulgare*, and many other invasive plant species that have become a menace across swathes of sub-Saharan Africa.

Biological control may have the added advantage of helping to resolve conflicts of interest, particularly over beneficial and commercially valuable agro-forestry species that are also invasive. Introduced bud-galling or seed-feeding insects that reduce the reproductive potential of invasive trees, but which otherwise have no impact on the growth of these useful trees, help to ensure that control can be achieved without at the same time sacrificing economic prospects.

Yet, while biocontrol may contribute significantly to the management of invasive plants of many different species, it remains just one component of an effective overall IAS management strategy. The principal value of biocontrol is that, in most cases, it lowers the costs of other, more costly management interventions such as mechanical and chemical control. Over time, however, these costs may in any case be offset by the benefits accruing from restored ecosystem productivity and function. Biocontrol also ensures that alien plant infestations can be controlled gradually – and without the ecological 'shock' that may occur when an infestation is suddenly removed or killed, leaving fallow land that is susceptible to further degradation and to re-infestation.

Another benefit associated with control programmes in some parts of the world is that of job creation. South Africa's Working for Water Programme, for example, has succeeded in creating jobs for thousands of otherwise unemployed people in poor or marginalised communities. Clearing invasive alien plant infestations and poverty alleviation go hand in hand in an initiative that has enabled the government in South Africa to address, at one fell swoop, two of the country's most intractable problems. Such a strategy could be emulated by other African countries where the combination of mushrooming unemployment and an increasingly degraded natural resource base resulting from alien plant invasions is threatening to spark social conflict, while also undermining progress towards achieving some Millennium Development Goals.


The centuries old Ethiopian cultural landscape will soon be lost as a result of invasive species ©Arne Witt

African countries that continue to ignore the threat posed by invasive plant species do so at their own peril, especially given how accelerating climate change is likely to exacerbate future plant invasions across the continent.

That said; there have been some positive developments on the continent – even in countries where the UNEP/GEF *Removing Barriers to Invasive Plant Management in Africa* (RBIPMA) Project was not active. Thanks to the project, the term 'invasive alien species' is now familiar to, and understood by, a great many African decision-makers at both the local and national levels and (in some cases) at the regional level as well. In general, people across Africa are more aware now of invasive alien species and of the threat such species pose than was the case ten, or even five, years ago.

Efforts to curb the importation and movement of invasive plants into and across international borders are being stepped up in some nations. Protected Area managers and conservation ecologists are now also generally more conscious of the threats that invasive plant species pose to biodiversity and ecosystem function. Information on the presence and distribution of invasive alien plant species is in the process of being gathered and collated in several countries, as the basis for developing long-term IAS management strategies.

Some agencies, such as the Kenya Wildlife Service (KWS), have taken matters a step further, and are already developing an Invasive Species Strategy, having for the first time allocated resources to the management of invasive plants within Protected Areas. The Kenya Plant Health Inspectorate (KEPHIS), meanwhile, is in the process of developing a national system of Early Detection and Rapid Response – another big step in the right direction.

In most African nations, however, a lack of available resources is still hampering the development and implementation of effective IAS management strategies. The RBIPMA Project has demonstrated that donor-funded projects can provide countries, not only with the impetus to initiate invasive species' management programmes, but also – and more importantly – with a foundation on which to go on building effective programmes of their own. In many cases then, it is the will and commitment of donor agencies that will determine, ultimately, whether Africa can win this war against what may yet turn out to be (if it is not so already) one of the greatest of all threats, not just to biodiversity, but to economic growth and prosperity as well.

Doum palms (*Hyphaene compressa*) widely used by communities in East Africa, are threatened by invasions of Mesquite (*Prosopis juliflora*) in East Africa ©Arne Witt

The broader picture

There are invasive alien species within all taxonomic groups – plants, animals, micro-organisms, and viruses – found on Planet Earth. So, while the focus of this book has been on the invasive plants, and on those plant invaders which are having a particularly severe impact on countries in sub-Saharan Africa, it seems fitting, here, to touch on some of the wider dimensions of the invasive alien species' threat …

APPENDIX

Collectively, invasive alien species – from all taxonomic groups – are recognised as posing one of the gravest threats, after direct habitat destruction, to the ecological and economic well-being of our planet. Of the more than 120,000 species of plants, animals and microbes that have become common pests around the globe, and which continue to cause massive damage to ecosystems, natural and managed, in lands as widely separated as the United States, the UK, Australia, South Africa, India and Brazil, by far the most destructive (after our own species, that is) are some of the smaller mammals we humans have transported around the globe – the rodents, above all.

Invasive mammals

Introduced species of rats and mice account for more than half of all the ecological and economic damage inflicted on most regions by non-human invasive mammal species. Two species in particular – the Black (Ship) Rat, *Rattus rattus*, and the Brown (House) Rat, *Rattus norvegicus*, native to South East Asia and China respectively – have, as we have seen (in Chapter One), been responsible for precipitating wave upon wave of extinctions among the fauna of many of the islands they have colonised over the past five centuries. They, together with the familiar House Mouse, *Mus musculus*, which is also native to Asia (probably to northern India), continue to exact a heavy toll, in most countries, on human agriculture and food production and storage (*see Accompanying Tables*).

Other rodent species, although very much more limited in their global distribution than the rats and the mice mentioned, have become an invasive menace in some regions. The North American Grey Squirrel, *Sciurus carolinensis*, for example, introduced into Britain and into northern Italy in the late 1940s as a pet species, has become a serious pest in both these parts of Europe. Here, the species – which strips the bark from trees – has caused extensive damage to forests and commercial tree plantations. It has also out-competed and replaced native European populations of the Red Squirrel, *Sciurus vulgaris*, which (suspicion has it) may be dying out after contracting a lethal parapox virus carried by the introduced Grey Squirrels.

LOSSES ATTRIBUTED TO INVASIVE ALIEN SPECIES IN THE UNITED STATES

PEST CATEGORY	ANNUAL LOSSES (US$)
Plants	148 million
Mammals – rats – other mammals	 19 billion 18.1 billion
Birds	1.1 billion
Reptiles and amphibians	6 million
Fishes	1 billion
Arthropods	2.1 billion
Molluscs	1.3 billion
Livestock diseases	9 billion
Human diseases	6.5 billion
Total	**58.3 billion**

Source: Pimentel et al. (2001)

The Nutria (or Coypu), *Myocaster coypus*, a large be-whiskered South American rodent, is another alien invader that has been widely introduced, into much of Europe, as well as into parts of the United States, South-East Asia and Africa. The hope, among early 20th-Century entrepreneurs, was that Nutrias might be 'farmed' commercially for their fur. It was not long, however, before some of the imported Nutrias escaped from the fur farms – or were released into the wild after their owners found that fur-farming, after all, was not a viable enterprise. The unwanted Nutrias went on to establish thriving populations along rivers and streams, where their burrowing habits and their voracious appetites for local plants have been the cause of severe riparian erosion and habitat loss.

Nutrias were imported into Kenya in the 1930s from fur farms in Britain. Some early British settlers set up fur farms in dams on highland streams emanating from Mount Kenya and the Aberdare Mountains. Some of the imported Nutrias are known to have escaped from the farms as early as 1935. Others escaped when dams were swept away by floods in the 1940s. Nutria's have since dispersed widely, invading rivers, streams, dams, wetlands and freshwater lakes (including Lake Naivasha) in, and to the east of, the Great Rift Valley in Kenya, where – just as in parts of Europe – the species has disrupted the native ecology of some riverbank and lake-shore environments.

Of the many species of small mammals we humans have transported deliberately to distant lands, few (barring the Domestic Cat, *Felis catus*) have had a more destructive impact on life on another continent than the European Rabbit, *Oryctolagus cuniculus*, in Australia. Native to southern Europe's Iberian Peninsula, wild rabbits were hunted in Neolithic times with domesticated ferrets, which would flush them out of their warrens. Rabbits were not themselves domesticated until as recently as the Middle-Ages – when monasteries in the south of France started raising live-captured wild rabbits for food.

Come the late 18th Century, and the colonisation of Australia, domesticated rabbits were shipped out and released into the wild, ostensibly to provide a familiar additional prey animal for Red Foxes, *Vulpes vulpes*, from Britain, which were introduced at roughly the same time (and which, in their own way, would go on to prove just as destructive). The impulse behind introducing these alien species was none other than the traditional British passion for fox-hunting. Initially, all the introduced domesticated rabbits died. Not to be deterred, the British tried again – and again. Eventually, at the fifth attempt, this time using wild rabbits captured in Spain, the settlers finally got their wish.

The rabbits, when they did finally become established, did so in such numbers that Australia has been trying ever since to get rid of them. The alien rabbits have become a plague, consuming at least half the pasture vegetation that might otherwise be available to those economically useful aliens, sheep and cattle. Between them, the rabbits and the foxes have devastated Australia's native fauna, driving several species into extinction and precipitating calamitous population crashes among other small herbivorous native mammals, which – if not hunted down and eaten by the foxes – are out-competed and displaced by the rabbits.

Domestic Cats, for their part, having been introduced into almost every habitat and region on Earth, are unrivalled as killers of the native birds, small mammals and reptiles they encounter. In the United States, more than 100 million cats (including an estimated 35 million feral animals) are believed to be responsible, annually, for killing about 566 million birds alone. *Felis catus* is thought to have been domesticated in a process going back over more than 6,000 years to ancient Egypt (where, first *Felis lybica*, and then hybrids of this species and of *Felis sylvestris*, are believed to have emerged). Domestic Cats, transported around the world on ships and used extensively for controlling vermin rodent populations, have had a devastating impact on the native fauna of many regions – and on that of islands especially. The Domestic Cat is now ranked among the 'Worst 100' alien invaders on the planet.

Invasive birds

Birds – migratory birds, that is – have been travelling around the globe far longer than we humans. So, natural ecosystems around the world, in both the summer and winter ranges of such migrants, have co-evolved over many thousands of years in synchrony with these birds' seasonal comings and goings. People, though, on settling in the past in faraway lands, have contrived, out of homesickness, to introduce some familiar resident songbirds from their homelands. Some of the alien non-migrant birds introduced in this way have gone on to become pests. Examples include the European Starling, *Sturnus vulgaris*, and the House Sparrow, *Passer domesticus*. Both are native to Eurasia and to North Africa. Both were carried around the world by European settlers in the 1890s.

The starlings have become particularly numerous and widespread in North America, South Africa and Australia, where their massive flocks crowd out native bird species, taking over nests and nesting sites and monopolising available insect prey. These birds also strip fruit from grapevines and other cultivated plants, and uproot and consume sprouting seedlings. The sparrows have found their niche around human settlements in parts of southern and eastern Africa, where – in some towns – they have become the dominant avian species, having usurped the nest holes and taken over the food niches of native birds.

Indian Crow (*Corvus splendens*) ©iStockimages

ECONOMIC LOSSES ATTRIBUTED TO INVASIVE ALIEN CREATURES

SPECIES	IMPACTED ECONOMIC ACTIVITY	COST (US$)	SOURCE
Introduced Rats and Mice	Damage to agriculture and food production in six large economies – in India – in the United States – in Brazil – in Great Britain – in South Africa – in Australia	56.4 billion/year 25 billion/year 19 billion/year 4.4 billion/year 4.1 billion/year 2.7 billion/year 1.2 billion/year	Pimentel et al. (2000)
European Rabbit, *Oryctolagus cuniculus*	– Agricultural losses in Australia	280 million/year	White & Newton-Cross (2000)
Nutria (Coypu), *Myocaster coypus*	– Damage to agriculture and river banks in Italy	2.8 million/year	Panzacchi et al. (2004)
European Green Crab, *Carcinus maenas*	– Damages to North Pacific Ocean fisheries affecting the US	44 million/year	Cohen et al. (1995)
Golden Apple Snail, *Pomacea canaliculata*	– Damage to rice in the Philippines	28–45 million/year	Naylor (1996)
Zebra Mussel, *Driessena polymorpha*	– Damages to industry in the US and Europe 750 million–1 billion (1998–2000)	750 million – 1 billion (1998–2000)	National Aquatic Nuisances Clearing House (2000)
Comb Jelly *Mnemiopsis leidyi*	– Lost anchovy fisheries in the Black Sea	17 million/year	Knowler (2005)
Varroa Mite, *Varroa destructor*	– Economic cost to bee-keeping in New Zealand	267–602 million (cumulative)	Wittenberg & Cock (2001)
Introduced disease organisms	– Cost to human, animal and plant health in the United States	41 billion/year	Daszak et al. (2000)

Both the starlings and the sparrows are known reservoirs, moreover, for several harmful pathogens, which because the birds live in such close proximity to people poses a public health risk.

A particularly menacing avian invader that also benefits from a close association with humans is the Indian House Crow, *Corvus splendens*. This brazen scavenger came to Africa in the 1890s, reportedly via Zanzibar, where at first its presence was found to be useful in helping to keep the island free of rubbish. The species has since become established along Africa's entire eastern coastline, from Suez in the north to the Cape of South Africa, having also occupied stretches of North Africa's Mediterranean coastline. It has been able to spread through cadging lifts on ships and on fishing boats travelling back and forth.

Indian House Crows have severely affected native wildlife populations. They eat the eggs and the chicks of many nesting birds, while preying heavily on frogs, lizards, small mammals, crabs, fish and insects. They also strip fruit from orchard trees and raid grain crops. They scavenge from rubbish dumps. They are not afraid of people and will dive-bomb children into parting with any food they may be carrying, or enter homesteads to pilfer scraps from kitchen tables. More worryingly, these aggressive scavengers are a public health hazard, being carriers of many pathogens, including those responsible for causing cholera, typhoid, dysentery and salmonella poisoning.

Invasive reptiles and amphibians

On the island of Guam in the West Pacific, one species of alien reptile, the Brown Tree Snake, *Bolga irregularis*, has achieved particular notoriety in having been responsible for wiping out most of the island's small indigenous fauna. Originally from Papua New Guinea (although it does also occur in coastal NE Australia and on some Melanesian islands), the species arrived on Guam, then the US Army's new Pacific Headquarters, as a stowaway in US military equipment being decommissioned after World War II.

On Guam, adult Brown Tree Snakes may reach lengths of almost three metres – considerably longer than in their native habitats, where body lengths seldom exceed 1.8 metres. In going on to dominate the island, the arboreal snakes have eaten their way through entire populations of indigenous birds, lizards and small mammals. Casualties have included species of birds and fruit bats that as crop pollinators and seed-dispersers had provided islanders with essential ecosystem services. By 1985, most of Guam's remaining forest bird species – then already listed as either Endangered or Threatened by the US Fish and Wildlife Service – were in reality virtually extinct.

The destructive impact in Australia of the now-ubiquitous Cane Toad, *Bufo marinus*, is a harrowing example of how the deliberate introduction of an alien

Brown tree snake (*Boiga irregularis*) ©iStockimages

Nile Perch

generalist can go horribly awry. Native to Central and South America, Cane Toads were introduced into parts of Queensland (from Hawaii) in 1935, in an effort to control native Cane Beetles, *Dermolepida albohirtum*, which had been damaging exotic sugar-cane plantations. The beetles eat the cane leaves, while their larvae feed on the roots of the plants.

Since their release, the Cane Toads have spread rapidly and multiplied – so much so that there are now more than 200 million of these amphibians in Australia. The toads produce a poisonous milky parotid secretion. This protects them from most indigenous predators, which have evolved no defence against such alien toxins. The result is that the toads have been able, over the course of their advance, to out-compete, outnumber and oust many native insectivores, particularly lizards. They appear to show little to no interest, however, in the beetles whose populations they were brought in to control.

Invasive fishes

The catastrophic impact of the introduced Nile Perch, *Lates nilotica*, on the biodiversity of Africa's Lake Victoria (described in detail in Chapter One) stands out as one of the most chilling examples of how an alien fish species can transform the whole ecology of a freshwater lake. In having led to the possible extinction, although this has never been proven scientifically and as such has been questioned by some, of no fewer than half of Lake Victoria's more than 400 native haplochromine cichlid fish species, the introduction, in the 1950s, of this monstrous and voracious predator is responsible for what has been described as the biggest mass-extinction of vertebrates in recorded history.

Another invasive alien fish species that is widespread in Africa and around the world is the Common Carp, *Cyprinus carpio*. Native to parts of Asia and Europe, this species – widely promoted as a valuable food source during the early part of the 20th Century – was introduced deliberately into lakes, dams and rivers in many countries. The species can grow to a prodigious size, reaching lengths of one metre, or longer, and weighing in at more than 30 kg. The Common Carp is an omnivorous bottom-dweller, sifting the beds of water bodies for plant matter and for aquatic insects, crustaceans, snails, worms and the spawn of other fish. Uprooting water plants, this 'grubbing' feeding behaviour disturbs bottom sediments, muddying the water column and reducing light penetration – rendering habitats unsuitable for native underwater plants and fish populations.

The Common Carp can itself withstand a wide range of conditions, thriving even in degraded, oxygen-poor environments. Its rapid growth and its extraordinary fecundity (a female may lay more than 100,000 eggs in a single season), have allowed it to dominate many of the water bodies into which it has been introduced.

INVASIVE MAMMALS IN BRITAIN

NUMBERS OF SOME INTRODUCED MAMMALS AT LARGE IN THE UNITED KINGDOM (2009)	
European Rabbit, *Oryctolagus cuniculus*	37 million
'Common' Rats – Black (Ship) Rat, *Rattus rattus* – Brown (House) Rat, *Rattus norvegicus*	6.8 million
House Mouse, *Mus musculus*	5 million
American Grey Squirrel, *Sciurus carolinensis*	2.5 million
PLUS	
People	61.5 million
Household Pets – Cats and Dogs	20.8 million

Source: Tracking Mammals Partnership, British Veterinary Association (2009)

Invasive molluscs

Snails of various species have shown, time and time again, how they can turn menacing invaders on being transported into new environments. Some snail species have been introduced as potential new food sources; some as exotic pets. Others have been spread unwittingly in garden-nursery and horticultural exports, very often via eggs embedded in potting soils. Historically, yet others have been introduced in the name of biocontrol, amid hopes (usually misplaced) that an aggressive newcomer might somehow overcome and eradicate the existing infestations of another invasive alien snail species.

As early as the 1940s, alien land molluscs had become serious agricultural crop pests in many regions. The most infamous of these species was the Giant African Snail, *Achatina fulica*, originally from East Africa. In India's Orissa State, this large species triggered a famine in 1946–1947 on irrupting suddenly and eating its way through rice paddies and fields of vegetables. Infestations have since created panic on islands in the Caribbean and in the United States, among other places. An eradication campaign in Florida finally succeeded in 1969, at a cost of more than US$ 1 million, in containing one potentially damaging infestation. A small boy, it turned out, had smuggled three of the giant snails into Miami in 1966 and

Giant African snail (*Achatina fulica*) ©iStockimages

ECONOMIC COSTS OF SOME RECENT OUTBREAKS OF ANIMAL DISEASES		
DISEASE AND OUTBREAK	**ANNUAL LOSSES (US$)**	**IMPACT ON GDP**
Bovine spongiform encephalopathy (BSE)	3.5 billion	– 0.4%
Foot and Mouth Disease (FMD), Chinese Province of Taiwan, 1997	6 billion	– 0.65%
Classical Swine Fever (CSF), Netherlands, 1997/1998	2.1 billion	– 0.75%
Foot and Mouth Disease (FMD), UK, 2001	10.5 billion	– 0.2%
Fishes	1 billion	
Avian influenza (Bird Flu), Vietnam, 2003/2004	0.5 billion	– 0.3 to – 1.8%
Avian influenza (Bird Flu), Netherlands, 2003	0.6 billion	Not available

Sources: FAO (2002, 2004), EU (2005)

released them in his grandmother's garden. The pet snails had come from Hawaii.

On Hawaii, the Giant African Snail had become such a menace that, in 1955, molluscs of another species, the Rosy Wolf Snail, *Euglandina rosea*, native to tropical North America, were introduced. The hope was that, as predators on other snails, they might eliminate the African invaders. This strategy was emulated in 1960 on the islands of Mauritius and Réunion, as well as on the Seychelles and Madagascar – all places where the Giant African Snails had been creating havoc. The Rosy Wolf Snails, though, found other prey more to their liking – and in such abundance that they too became an invasive threat. On Mauritius, they have been responsible for the extinction of at least 24 of the island's 106 endemic snail species. There, as on Hawaii and elsewhere, they had little impact on the Giant African Snails.

Undeterred by this sequence of events, entrepreneurs nevertheless proceeded in the early 1980s to introduce, into these and many other habitats around the world, another alien mollusc species – the Golden Apple Snail, *Pomacea canaliculata*. Native to South America, this aquatic species too was championed at the time as a potentially valuable new food source. But the envisaged markets never materialised, and the species has turned out instead to be a voracious pest. In the Philippines, it has invaded more than half of all rice paddies, reducing overall rice yields by more than 50%. On the islands of Hawaii, wracked already by infestations of Giant African and Rosy Wolf Snails, the Golden Apple Snails now routinely eat their way through much of the taro crop, the traditional staple, before the plants are even ready to harvest.

Invasive aquatic arthropods

One alien invader that has, over the past 50 years, transformed the ecology of many of East Africa's rivers, wetlands and lakes (including Lake Victoria) is the Louisiana Red Swamp Crayfish, *Procambarus clarkii*. This prolific and aggressive crustacean was introduced, initially into Lake Naivasha in Kenya, in the 1970s. While local people do not eat the crayfish, the hope was the species might form the basis of a lucrative export industry, as people in Europe and elsewhere consider their flesh a delicacy. Although successful to begin with, the export industry collapsed after the crayfish – inordinately fond of their new Naivasha base – proceeded, literally, to eat their way out of house and home. Their population irrupted in the 1980s and before long the crustaceans had devoured most of the plants beneath the water's surface, displacing in the process many of the lake's other small aquatic creatures.

With nothing left to eat and nowhere to hide, the exposed crustaceans were easily picked off – mainly by Large-mouthed (Black) Bass, *Micropterus salmoides*, a North American 'sport' fish that had been introduced more than 50 years earlier, and which had long since gobbled up many of Lake Naivasha's indigenous fish, including a species of small freshwater sardine (now extinct) that had been known only from this one locality. Thanks also to various native avian predators (ibises, storks, herons, and eagles), the famished crayfish population crashed. Native aquatic plants began to regenerate. The introduction in 1989 of the Water Hyacinth came to the rescue of the crayfish, however. They do not eat the plant, but in being able to burrow underneath its spongy mats, the crayfish again found perfect cover. They also thrive on the oozing bacterial sludge of decomposing organic matter found beneath the hyacinth mats. So crayfish numbers not only recovered; they irrupted again.

The Louisiana Red Swamp Crayfish has since found its way into many other lakes, wetlands and rivers in East Africa. On its travels, the species has succeeded in out-competing and crowding out a host of native species, including the Freshwater Crab, *Potamonautes neumannii*. The abundant crayfish may appear, superficially, to present native aquatic predators, such as the African Clawless Otter, *Aonyx capensis*, with a plentiful new food source. Yet, as happened in Lake Naivasha, crayfish abundance is subject to alternating cycles of 'boom or bust'. This instability undermines the long-term food security of specialised aquatic predators, such as the otters, which have long depended on a diet made up almost exclusively of Freshwater Crabs.

Louisiana Red Swamp Crayfish (*Procambarus clarki*) ©iStockimages

Invasive insects

Many of the world's most widespread destructive agricultural pests are insects, of which many species have become invasive on being deposited in new environments – often in contaminated imports of grain or fresh produce. Alien beetle infestations can have dire socio-economic consequences. The Khapra Beetle, *Trogoderma granarium*, thought to have evolved on the Indian sub-continent, is a perpetual threat to the granaries and food stocks of many regions. The Larger Grain Borer, *Prostephanus truncates*, from Central and South America, has had a devastating impact on farm-stored maize reserves across sub-Saharan Africa since the 1970s, when the species was first detected on the African continent.

Invasive alien ants, meanwhile, of numerous species, have permanently altered the ecology of new environments they have colonised around the world. The Argentine Ant, *Linepithema humile*, has had a particularly severe impact on indigenous Fynbos plant communities in South Africa's Cape Floral Region. The species is thought to have been introduced in horse fodder imported from Argentina for the British cavalry during the Anglo–Boer War of 1899–1902. (Also brought in with this fodder was the Mexican Marigold, *Tagetes minuta*, later dubbed *Khakibos*, or Khaki Bush, on account of the khaki uniforms the British soldiers then wore. The marigold too has since proliferated, becoming a loathsome weed in many parts of sub-Saharan Africa.)

The Cape Fynbos biome, one of the world's most bio-diverse plant communities, has co-evolved in a mutually beneficial association with various native species of ants. Many Fynbos plants rely on the ants for dispersing and 'planting' their seeds. In return for carrying seeds underground and out of harm's way, the native ants receive food parcels called elaiosomes, which come attached to the seeds. The alien Argentine Ants not only out-compete and displace the native ants; they also cheat the system by eating the elaiosomes above ground, especially those of large seeds, without burying them. Abandoned seeds that do not perish on exposure to the sun are then either destroyed by fires or else eaten by foraging rodents. Regeneration of the Fynbos is severely hampered as a result.

Exactly this kind of scenario is mirrored in many other regions of the world that have been colonised by Argentine Ants or by invasive alien ants of other species. The Red Fire Ant, *Solenopsis invicta*, originally from South America, and the Big-headed Ant, *Pheidole megacephala*, once confined to the island of Mauritius, are two other now-widespread and damaging invasive alien ant species. By driving out native insect pollinators and seed-dispersers, both have sabotaged co-operative relationships that for millennia have underpinned the ecology of entire habitats and pasture ecosystems. By disrupting the essential ecosystem services the native insects deliver, the invaders have impaired regeneration among native plants. This has created 'weak spots' in habitat defences that aggressive alien plant invaders may go on to exploit. Though ants may be small, their disruptive impact in alien swarms is often out of all proportion to their size.

Of the more than 20,000 wild bee species that are known to occur on the planet, we humans have come to depend – for honey, as well as for pollinating many of our food crops – on one species above all others. That species is the common Honey Bee, *Apis mellifera*. The Honey Bee has its origins in eastern Africa. Thousands of years ago, after dispersing with early humans into different parts of Europe and central Asia, African Honey Bees evolved into the more than 20 Honey-Bee subspecies we know today. In the 17th Century, colonies of several of these 'European' subspecies were shipped over to North America.

There, as in many other agricultural economies, the alien bees very soon became indispensable pollinators of a wide range of introduced alien food crops. Then, in the 20th Century, an aggressive southern African Honey-Bee subspecies, *A. m. scutellata*, the so-called 'Killer Bee', which had been introduced into Brazil in 1956 in a bid to boost honey production, invaded North America, hybridizing with and replacing some of the introduced Honey-

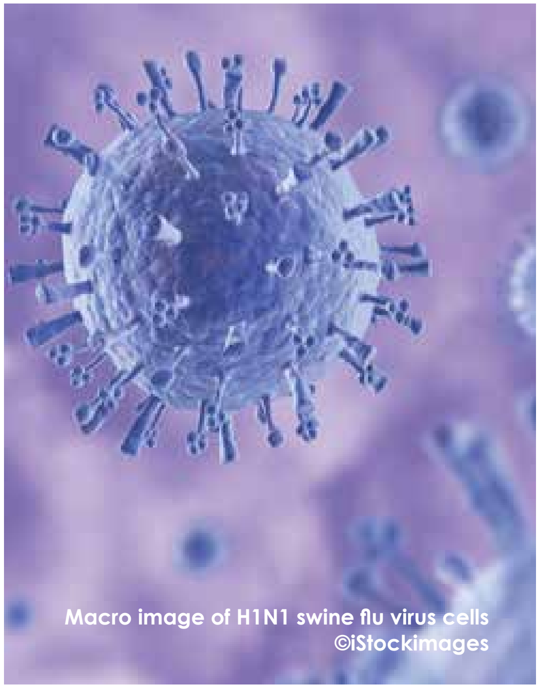
Bee populations. More recently, in 1987, managed Honey-Bee colonies across North America suddenly crashed. Similar crashes followed in Europe and in many other regions – some as far away as New Zealand. Honey-Bee populations in Africa suffered the same fate …

Invasive mites

Implicated as one possible cause of 'Colony Collapse Disorder' (a host of other factors have also been implicated including habitat destruction and excessive pesticide use), as the bee die-offs were soon being called, is a tiny alien parasite, recorded first in Java in 1904 and later in South-East Asia, where it had been found afflicting bees of another *Apis* species, *A. cerana*. Known as the Varroa Mite, *V. destructor*, the virulent parasite feeds on the body fluids of Honey Bees at all stages in their development and infects some bees with a wasting condition called varroatosis, characterised by wing and limb deformities.

The spread of the Varroa Mite is a worry, not just for bee-keepers, but for some entire nations as well, given the extent to which humanity depends on the pollination services delivered by Honey Bees. As the primary agents of pollination, bees are essential to all life. Without them, we are doomed.

Varroa Mite (*V.destructor*) on a honey bee ©iStockimages



Macro image of H1N1 swine flu virus cells ©iStockimages

Invasive micro-organisms

Alien invaders that have ravaged human populations down the ages include a succession of lethal pathogens. The viruses responsible for smallpox and measles, carried to the Americas in the 16th Century with European colonisers, contributed to the collapse of the once mighty Aztec and Inca empires. While the smallpox virus may have originated in Africa, the epicentre for its spread was in Asia, whence – like rats – it was carried into Europe on mediaeval trade routes. The arrival in Africa in the 1880s of a new strain of this ancient virus devastated human populations at a time when rinderpest and other alien cattle diseases (such as bovine pleuro-pneumonia) had also just arrived with infected cattle from Eurasia, and were wiping out livestock and wild bovid herds across the continent.

In more recent times, alien strains of ‘bird flu’ and of ‘swine flu’ have sparked recurrent global health scares, invoking fears of a new pandemic on the scale of the ‘Spanish Flu’ that in 1918–1920 killed more than 60 million people – the equivalent then of more than three per cent of the entire human race. The influenza virus has its origin in birds, but is carried by domestic pigs, which on being infected with multiple strains may act as ‘mixers’ in enabling new viral strains to evolve.

Some of the new strains may become zoonotic, meaning they can be passed on to and infect humans as well – just as the bubonic plague bacterium was able to ‘jump’ from rats into people via fleas. On today’s high-speed air travel networks, such zoonotic diseases can then spread rapidly around the world. The proliferation since the 1980s of HIV-Aids, another invasive alien zoonotic disease, provides a chilling reminder of just how fast, in this day and age of accelerating globalisation, a lowly virus can spread to every part of every continent on Earth.

THE WORLD’S ‘WORST 100’

The Global Invasive Species Database (GISD), maintained by the Invasive Species Specialist Group (ISSG) of the International Union for the Conservation of Nature (IUCN), www.issg.org/database, runs a list of the World’s Worst Invasive Alien Species. The list of shame for 2006 read as follows:

Micro-organisms

Avian Malaria, *Plasmodium relictum*
Banana Bunchy Top Virus
Chestnut Blight, *Cryphonectria parasitica*
Crayfish Plague, *Aphanomyces astaci*
Dutch Elm-Disease, *Ophiostoma ulmi*
Frog Chytrid Fungus, *Batrachochytrium dendrobatidis*
Phytopthora Root Rot, *Phytophthora cinnamomi*
Rinderpest Virus

Aquatic Plants

Caulerpa Seaweed, *Caulerpa taxifolia*
Common Cordgrass, *Spartina anglica*
Wakame Seaweed, *Undaria pinnatifida*
Water Hyacinth, *Eichhornia crassipes*

Land Plants

African Flame Tree, *Spathodea campanulata*
Black Wattle, *Acacia mearnsii*
Brazilian Pepper-Tree, *Schinus terebinthifolius*
Cluster Pine, *Pinus pinaster*
Cogon Grass, *Imperata cylindrica*
Erect Prickly Pear, *Opuntia stricta*
Fire Tree, *Myrica faya*
Giant Reed, *Arundo donax*

Giant Sensitive Plant, *Mimosa pigra*
Gorse, *Ulex europaeus*
Himalayan Rasperry, *Rubus ellipticus*
Hiptage, *Hiptage benghalensis*
Japanese Knotweed, *Fallopia japonica*
Kahili Ginger, *Hedychium gardnerianum*
Koster's Curse, *Clidemia hirta*
Kudzu Weed, *Pueraria montana*
Lantana, *Lantana camara*
Leafy Spurge, *Euphorbia esula*
Leucaena, *Leucaena leucocephala*
Melaleuca, *Melaleuca quinquenervia*
Mesquite, *Prosopis glandulosa*
Miconia, *Miconia calvescens*
Mile-a-Minute Weed, *Mikania micrantha*
Privet, *Ligustrum robustum*
Pumpwood, *Cecropia peltata*
Purple Loosestrife, *Lythrum salicaria*
Quinine Tree, *Cinchona pubescens*
Shoebutton Ardisia, *Ardisia elliptica*
Strawberry Guava, *Psidium cattleianum*
Tamarisk, *Tamarix ramosissima*
Triffid (Siam) Weed, *Chromolaena odorata*
Wedelia, *Sphagneticola trilobata*

Aquatic Invertebrates

Chinese Mitten Crab, *Eriocheir sinensis*
Comb Jelly, *Mnemiopsis leidyi*
European Green Crab, *Carcinus maenas*
Fish Hook Flea, *Cercopagis pengoi*
Golden Apple Snail, *Pomacea canaliculata*
Marine Clam, *Potamocorbula amurensis*
Mediterranean Mussel, *Mytilus galloprovincialis*
Northern Pacific Sea Star, *Asterias amurensis*
Zebra Mussel, *Dreissena polymorpha*

Land Vertebrates

Argentine Ant, *Linepithema humile*
Asian Long-horned Beetle, *Anoplophora glabripennis*
Asian Tiger-Mosquito, *Aedes albopictus*
Big-headed Ant, *Pheidole megacephala*
Common Malaria Mosquito, *Anopheles quadrimaculatus*
Common Wasp, *Vespula vulgars*
Crazy Ant, *Anoplolepis gracilipes*
Cypress Aphid, *Cinara cupressi*
Flatworm, *Platydemus manokwari*
Formosan Termite, *Coptotermes formosanus shiraki*
Giant African Snail, *Achatina fulica*
Gypsy Moth, *Lymantria dispar*
Khapra Beetle, *Trogoderma granarium*
Little Fire Ant, *Wasmannia aropunctata*
Red Fire Ant, *Solenopsis invicta*
Rosy Wolf Snail, *Euglandina rosea*
Sweet Potato Whitefly, *Bemisia tabaci*

Fish

Brown Trout, *Salmo trutta*
Common Carp, *Cyprinus carpio*
Largemouth Bass, *Micropterus salmoides*
Mozambique Tilapia, *Oreochromis mossambicus*
Nile Perch, *Lates niloticus*
Rainbow Trot, *Oncorhynchus mykiss*
Walking Catfish, *Clarias batrachus*
Western Mosquito Fish, *Gambusia affinis*

Amphibians

Bullfrog, *Rana catesbeiana*
Cane Toad, *Bufo marinus*
Caribbean Tree Frog, *Eleutherodactylus coqui*

Reptiles

Brown Tree Snake, *Boiga irregularis*
Red-eared Slider Turtle, *Trachemys scripta*

Birds

Common Starling, *Sturnus vulgaris*
Indian Mynah, *Acridotheres tristis*
Red-vented Bulbul, *Pycnonotus cafer*

Mammals

Black (Ship) Rat, *Rattus rattus*
Brushtail Possum, *Trichosurus vulpecula*
Domestic Cat, *Felis catus*
European Rabbit, *Oryctolagus cuniculus*
Goat, *Capra hircus*
Grey Squirrel, *Sciurus carlinensis*
House Mouse, *Mus musculus*
Macaque Monkey, *Macaca fascicularis*
Nutria (Coypu), *Mycocstor coypus*
Pig, *Sus scrofa*
Red Deer, *Cervus elaphus*
Red Fox, *Vulpes vulpes*
Small Indian Mongoose, *Herpestes javanicus*
Stoat, *Mustela erminea*

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USEFUL WEBSITES

African Convention on the Conservation of Nature and Natural Resources **www.au.int**

CABI Invasive Species Compendium (ISC) **www.cabi.org/isc**

Convention on Biological Diversity (CBD) **www.cbd.int**

Convention on Wetlands of International Importance (RAMSAR) **www.ramsar.org**

Convention on the Establishment of the Lake Victoria Fisheries Organisation **www.kenyalaw.org**

Forest Invasive Species Network for Africa (FISNA) **www.fao.org/forestry/fisna/en**

Global Invasive Species Database (GISD) **www.issg.org/database/welcome**

International Plant Protection Convention (IPPC) **www.ippc.int**

New Partnership for Africa's Development (NEPAD) **www.nepad.org**

Pacific Island Ecosystems at Risk (PIER) **www.hear.org/pier**

Phytosanitary Convention for Africa **www.au.int**

Scientific Committee on Problems of the Environment (SCOPE) **www.icsu-scope.org**

USDA National Invasive Species Information Centre **www.invasivespeciesinfo.gov**

South African Working for Water Programme (WfW) **www.environment.gov.za**

GLOSSARY

Alien Invasive Species: An alien species whose introduction and/or spread threatens native biodiversity (CBD); An alien species which, on becoming established in natural or semi-natural ecosystems or habitats, acts as an agent of change and threatens native biological diversity (IUCN).

Alien species: A species, subspecies, or lower taxon introduced outside its natural past or present distribution range; includes any part (gametes, eggs, seeds, or propagules) of such an organism that might survive and subsequently reproduce; i.e. an alien species is an individual or a population of any non-native (= exotic, foreign, non-indigenous, introduced) organism, or any viable part thereof, at any life-stage, that is present in an area, having been introduced into that area by human agency (CBD); A species, subspecies, or lower taxon (or any part thereof, including gametes or propagules, capable of surviving and of going on to reproduce) that occurs outside its natural range, past or present, and which has the potential to disperse outside the range it occupies naturally into areas it could occupy only through direct or indirect introduction or care by humans (IUCN). A species that occurs outside its historically known natural range as a result of intentional or accidental dispersal by human activities; also known as an exotic, non-native, or introduced species (UNEP–WCMC).

Basal treatment: Application of herbicide to the main stem or trunk of a plant from ground level to a height of (at most) about one metre.

Biocontrol species: An alien organism released intentionally to consume, infect, or otherwise debilitate a particular alien target species, with the aim of decreasing the latter's population size and density. Note: Possible limited specificity among biocontrol species is of concern, as some native (non-target) species may also be negatively affected (ICES).

Biological control agent: A natural enemy, antagonist, or competitor or other organism that is used for pest control (IPPC).

Biological control (biocontrol): A pest control strategy making use of living natural enemies, antagonists or competitors, or of other self-replicating biotic entities.

Chemical management: the application of herbicides or of plant growth regulators to disrupt the growth and spread of plants of unwanted species.

Containment: Application of sanitary or phytosanitary measures in and around an infested area to prevent the spread of a pest species (IPPC); • Maintaining a managed buffer zone separating pest-infested areas from largely non-infested areas where eradication efforts are under way.

Control (of a pest): Suppression, containment, or eradication of a pest population (IPPC).

Disturbance: An event or a change in an environment which, by altering the composition and successional status of that environment's biological community, may deflect succession on to a new trajectory; examples of such events are forest fires, hurricanes, glaciations, agricultural expansion, and urbanisation (Art, 1993).

Ecosystem: A dynamic complex of plant, animal and micro-organism communities and their non-living environment, inter-acting as a functional unit (CBD); A dynamic complex of plant, animal and micro-organism communities and their abiotic environment, inter-acting as a functional unit (IPPC).

Entry (of a pest): Movement of a pest into an area where that pest species is not yet present or where its distribution is limited or is being officially controlled (IPPC).

Eradication: Application of phytosanitary measures to eliminate a pest species from an area (IPPC); Permanent elimination of a targeted pest species or population from a specified area within a specified time period.

Establishment: The process whereby an alien species, having been introduced into a new habitat, succeeds in producing viable offspring with the likelihood of continued survival (CBD); Perpetuation, for the foreseeable future, of a pest species within an area (IPPC); Settling of an introduced species in a new area, where it can survive and reproduce without human intervention, protection, or support.

Exotic species: A species that exists freely within an area, but which is not native to that area; also refers to animals of species or of taxa that originate from outside a country in which they are held, either in captive or free-ranging populations (UNEP–WCMC); See also definitions for **Alien species** and **Introduced species**.

Foliar application: Application of herbicide to the leaves or foliage of plants.

Foreign species: See definition for **Alien species**

Frill (or Frilling): A series of overlapping axe or panga (machete) incisions made around the circumference of tree trunks, followed by the application of herbicide.

Girdling: Complete removal (ring-debarking) of a band of bark from around the circumference of a woody stem.

Herbicides: Chemical substances, either naturally occurring or artificially formulated, whose application alters a plant's metabolic processes, so the plant is either killed, or its growth is suppressed or altered in such a way as to inhibit its ability to function or to propagate.

Host range: Species which, under natural conditions, are capable of sustaining a specific pest or other organism (IPPC).

Integrated Pest Management (IPM): A combination of measures resulting in effective long-term prevention or suppression of pests; • An integrated approach to weed management combines elements of cultural practice with biological and chemical control interventions designed to have minimal impacts on environments and people (Heutte and Bella, 2003).

Indigenous (=native) species: A species or lower taxon living within its natural range (past or present), or in areas it would be capable of reaching and of occupying through using its own natural dispersal systems (ICES, modified after CBD, GISP).

Intentional introduction: Deliberate movement and/or release by humans of an alien species outside its natural range (CBD); An introduction made deliberately by humans, involving the purposeful movement of a species outside its natural range or beyond the reach of its natural dispersal potential; such introductions may be authorised or unauthorised (IUCN).

Introduced (=non-indigenous, =exotic) species: Any species transported intentionally or accidentally by a human-mediated vector into habitats located outside its native range. Note: Secondary introductions may be the result of transportation by natural, as well as by human-mediated vectors (ICES); •See also definition for **Alien species**

Introduction: Deliberate or accidental release into the environment of any given territory of an organism belonging to a non-native species or taxon – i.e. one that has not been observed, in historical times, as a naturally occurring and self-sustaining population in that territory (Bern Convention); Movement by human agency, indirectly or directly, of an alien species outside its natural distribution range, past or present, either within a country or between countries, or into or through areas that are beyond national jurisdiction (CBD); Entry of a pest resulting in its establishment (IPPC); Movement, by human agency, of a species, subspecies, or lower taxon (or any part thereof, including gametes or propagules) that might survive and reproduce outside its natural range, past or present, either within a country or between countries (IUCN).

Introduction (of a biological control agent): The release of a biological control agent into an ecosystem where it has never previously existed (IPPC).

Invasive Alien Species (IAS): An alien species whose introduction and/or spread threatens biological diversity (CBD); An alien species which, on becoming established in natural or semi-natural ecosystems or habitats, acts as an agent of change and threatens native biological diversity (IUCN).

Management: Any activity that prevents an alien species from gaining entry, or which prevents such a species, once in a country or area, from establishing, reproducing, or dispersing itself.

Manual control: Removal of invasive plants or weeds by hand-pulling or with tools such as shovels, axes, pangas (machetes), rakes, hoes, saws, or hand clippers, which may be used for the cutting and/or removal from target plants of their fruits, flowers, stems, leaves and/or exposed roots (Heutte and Bella, 2003).

Mechanical control: Removal of invasive plants or weeds with motorised equipment such as bulldozers, mechanical harvesters, mowers, 'weed-whackers', or tractor-drawn ploughs, disks or sweepers (Heutte and Bella, 2003).

Monitoring: An ongoing official process of assessing and of verifying phytosanitary conditions (IPPC).

National plant protection organisation: The official service established by a government to discharge the functions specified for IPPC compliance (IPPC).

Native (=indigenous) species: Any species, or subspecies, variety, or other lower taxon within a given area that in historical times has been observed to form a naturally occurring and self-sustaining population (Bern Convention); A species, subspecies, or lower taxon occurring within its natural range, past or present, or within the range of its natural dispersal potential, i.e. without the influence, indirect or direct, of humans or human-mediated vectors (IUCN); Plants, animals, fungi, and micro-organisms of species and of taxa that occur naturally in a given area or region (UNEP–WCMC); See also definition of **Indigenous species**

Natural enemy: An organism that, in its area of origin, depends on and lives at the expense of another organism, whose populations it may help to limit. Such enemies include parasitoids, parasites, predators, phytophagous organisms, and pathogens (IPPC).

New introduction: The human-mediated movement of a species outside its present distribution range (ICES).

Non-indigenous species: See definitions for **Introduced species** and **Alien species**

Non-native species: See definition for **Alien species**

Pathway: Any avenue or means that allows the entry or spread of a pest (IPPC); •Any means or route enabling an invasive species to move from its place of origin (or from another habitat it has infested) into an area where it has not occurred before.

Pesticide: Any substance, or mixture of substances, that is used to control plant and animal life.

Pest: Any species, strain or biotype of plant, or animal or pathogenic organism that is injurious to plants or to plant products (IPPC).

Pest risk analysis (agreed interpretation): The process of evaluating biological or other scientific or economic evidence to determine whether or not an organism is a pest; whether it should be subject to regulation, and (if so) what phytosanitary measures might need to be taken against it (IPPC).

Pest risk (for quarantine pests): The probability of the introduction and spread of a pest and the magnitude of the potential associated economic consequences (IPPC).

Pest risk management (for quarantine pests): Evaluation and selection of options to reduce the risk of a pest's introduction and spread (IPPC).

Phytosanitary certificate: An official document on paper or its official electronic equivalent, drawn up in a manner that is consistent with the model certificates of the IPPC, attesting that a trade consignment meets phytosanitary import requirements (IPPC).

Phytosanitary measure: Any legislation, regulation, or official procedure that is designed to prevent the introduction and/or spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests (IPPC).

Prohibition: A phytosanitary regulation forbidding the importation or movement of specified pests or commodities (IPPC).

Quarantine: Official confinement of regulated articles for observation or research, or for further inspection, testing, or treatment (IPPC).

Quarantine pest: An economically potentially disruptive pest that is not yet present in an area, or whose distribution there is limited or being officially controlled (IPPC).

Regulated article: Any plant or plant product, or its packaging, or container or place of storage or means of conveyance, or its accompanying soil or other associated objects or materials, which may be capable of harbouring or spreading pests, and for which phytosanitary measures are deemed necessary – particularly where international transportation is involved (IPPC).

Release (into the environment): Intentional liberation of an organism into the environment (IPPC).

Restoration: Removal of noxious weed species and the re-establishment of desirable plant communities.

Risk analysis: (1) Assessment of the consequences of introduction of an alien species and of the likelihood of its establishment, using science-based information (i.e. risk assessment); and (2) Identification of measures that can be taken to reduce or to manage these risks (i.e. risk management), taking into account socio-economic and cultural considerations (CBD); See also definition for **Pest risk analysis**

Risk assessment: Evaluation of the likelihood of entry, establishment, or spread of a pest or disease within the territory of an importer, according to sanitary or phytosanitary measures that might be applied, and evaluation of the potential associated biological and economic consequences; or evaluation of potential adverse effects on human or animal health arising from the presence of additives, contaminants, toxins, or disease-causing organisms in food, beverages or feedstuffs

(WTO); See also definition for **Pest risk analysis**

Risk management: See definition for **Pest risk management**

Sanitary or phytosanitary measure: Any measure applied within a territory in order: (a) to protect animal or plant life or health from risks arising from the entry, establishment, or spread of pests, diseases or disease-carrying organisms; (b) to protect human or animal life or health from risks arising from the presence of additives, contaminants, toxins or disease-causing organisms in foods, beverages or feedstuffs; (c) to protect human life or health from risks arising from diseases carried by animals, plants, or products thereof, or from risks associated with the entry, establishment, or spread of pests; or (d) to prevent or to limit other damaging impacts arising from the entry, establishment, or spread of pests (WTO).

Spread: Expansion of the geographical distribution of a pest within an area (IPPC).

Surveillance: An official process of collecting and recording data on the occurrence or absence of pests through routine surveys, monitoring or other procedures (IPPC).

Transferred (=transplanted) species: Any species intentionally or accidentally transported to and released in an area, or areas, where there are already established populations of that species, and which may have the effect there of boosting the gene pool of the introduced species (ICES).

Tree injection: Method for administering herbicides under the bark and into the actively growing tissues of a tree.

Unintentional introduction: Any species whose introduction is not the result of a deliberate human act (CBD); A species that is introduced accidentally, through utilising humans or human delivery systems as vectors for dispersal outside its natural range (IUCN).

Vector: Any living or non-living carrier which, intentionally or unintentionally, transports living organisms (ICES).

Sources used

CBD: Decision VI/23* of the Conference of the Parties to the CBD, Annex, footnote to the Introduction.

IPPC: International Plant Protection Convention; International Standard for Phytosanitary Measure # 5 (Glossary of Phytosanitary Terms), 2006.

IUCN: Guidelines for the Prevention of Biodiversity Loss Caused by Alien Invasive Species (2000).

WTO: World Trade Organisation; Agreement on the Application of Sanitary and Phytosanitary Measures.

ICES: International Council for the Exploration of the Sea; Code of Practice on the Introduction and Transfer of Marine Organisms (2005)

UNEP–WCMC: UNEP World Conservation Monitoring Centre; Glossary of Biodiversity Terms (http://www.unep-wcmc.org/reception/glossary).

Bern Convention: Recommendations Nos. 57 and 99 of the Standing Committee of the Convention on the Conservation of European Wildlife and Natural Habitats.

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INVASIVE ALIEN PLANTS AND THEIR MANAGEMENT IN AFRICA

The **Removing Barriers to Invasive Plant Management in Africa Project**, implemented in four African nations (Ethiopia, Ghana, Uganda and Zambia) between 2005 and 2010, stands out as one of the most wide-ranging and ambitious campaigns yet undertaken in the global effort to 'scale up' the fight against damaging impacts arising from the spread of invasive alien species.

This informative and beautifully illustrated book is one of many outcomes of this four-year UNEP/GEF project. It sheds valuable light, not just on the huge challenges facing sub-Saharan Africa and many other parts of the developing world wracked by **alien plant invasions**, but also on the broader global dimensions of the invasive alien species' menace – now universally recognised as one of the gravest threats to the ecological, social and economic well-being of the planet.

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