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**Lead author and co-editor** Sue Matthews

**Editor and project manager** Kobie Brand

## Major contributors

Major contributors

Silvia R. Ziller

Sergio Zalba

Augustin Iriarte

María Piedad Baptiste

Maj de Poorter

Mariana Cattaneo

Charlotte Causton

Lynn Jackson

## The following people are gratefully acknowledged for additional contributions

Arturo Mora

Carola Warner

Jeffrey McCrary

Geoffrey Howard

Ana Sancho

Tom Paulsom

Alan Tye

Alex Brown

Evangelina Natale

John Gaskin

Imene Meliane

Marnie Campbell

Paul Downey

Diego Gil-Agudelo

Hector Rios Alzate

Paul Ouboter

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## Design and finished art

Runette Louw and Jenny Young

## Illustrators

Izak Vollgraaff

Doug Powell

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## FOREWORD



To date, South America has largely ignored the presence and impacts of invasive alien species on biodiversity and natural systems. This needs to change as the South American continent has more to lose than most other regions, being home to more than 20% of the planet's species. The region also has the best share of natural habitat left in the world.

Although to the general public these may just be another plant or animal, invasive alien species are everywhere: from rats in our urban areas to species such as the giant African snail and African grasses in the most remote spots deep in the Amazon rain forest. Insufficient assessments have been undertaken to enable us to understand how large the problem really is. In the meantime, public programmes continue to foster the cultivation of new non-native species through new introductions and re-introductions. This reflects a lack of scientific knowledge, as well as a lack of common sense in dealing with natural ecosystems according to the Precautionary Principle prescribed by the Convention on Biological Diversity.

Damage to natural ecosystems, especially when invasive alien species are part of the process, is usually irreversible. Consequences go far beyond the availability of financial resources to fix these problems: they create long-lasting impacts and can lead to extinction, so the best alternative is still to avoid creating them in the first place.

Few countries in the world have taken serious action to prevent the growing problem of invasive species. South America needs to learn from these experiences. Countries will need to act fast to stop new introductions. They should:

- build risk assessment processes that include environmental elements
- establish efficient prevention systems
- create rapid response capacity upon early detection of invasive species, and
- develop legal frameworks to appropriately deal with different species in natural and in production systems.

These efforts can only lead to positive results if linked to awareness-raising at all levels, from public knowledge to scientific expertise. This publication is part of a popular series of GISP booklets focusing on invaded regions across the globe, and is not intended as a technical book containing complete lists of all invasive species in South America. Rather, it gives an overview of the problem facing our Continent, highlighting some of the more serious and widespread invaders. Of course there are many more invasive species present across South America and we hope that this publication will make policy makers and managers alike more aware of the scale and spread of the problem.

We also hope that readers will understand that this massive invasion can only be dealt with if there is public cooperation at all levels. We need citizens to refrain from moving plants or seeds around, cultivating invasive species, or releasing pets into the wild. We need producers to control the invasive species they occasionally cultivate, and to find alternatives compatible with long-term sustainability. Many solutions are available – simple and cheap in technical terms, but complex when human interests are involved especially because of a general lack of knowledge and respect for biodiversity. We'd like this book to have at least a little effect on your vision of nature and of the future, and on your understanding that you can also help prevent the loss of precious species and ecosystem functions and services.

**Dr. Silvia R. Ziller**

Founder and Executive Director  
The Horus Institute for Environmental Conservation and Development  
Coordinator, South America Invasive Species Program  
The Nature Conservancy

# INTRODUCTION TO BIOLOGICAL INVASIONS

## Concepts and Definitions

The movement of biological species has been one of the phenomena that shaped the history of life on Earth. Horses, mastodons and bison came from Siberia into America across the Bering Strait, probably following the same route as our human ancestors. In a similar way, North and South America interchanged complete sets of species in the successive outcrops and sinks of the Panamá isthmus. In this way, the distribution of species in a given age results from the balance between migration and extinction.



Nevertheless, in the last few hundred years an unprecedented force has changed the distribution of species on the planet. This new biogeographic dynamic has humans playing the main role. Throughout its history, humanity has transported thousands of species away from their original distribution ranges. Many animals and plants were and are moved voluntarily to provide food security or the availability of fuel, building materials and other needs for different human activities. Others travel unnoticed in seeds or wood shipments or in ballast water. Also frequent are introductions of exotic species promoted by economic

development projects based on technical arguments of doubtful legitimacy that promise great rewards derived from the introductions and do not consider, or avoid to point out, the potential risks on cultural, economic and environmental values.

The growing movement of species away from their natural ranges by human means has also led to the appearance of a set of terms intended to define the different variants of this phenomenon.

An **alien** or **introduced** species is one coming from a different habitat or region. Sometimes this definition coincides with the political borders of a country, and so a species is considered exotic if it was brought from another country. This concept is adequate to set politics and regulations at the national level but it has important restrictions from the point of view of managing biological invasions because the movement of organisms inside a country can be a problem of great concern, just as bad as the importation of a new species. For instance, the translocation of the tucunaré (*Cichla ocellaris*) from the Amazon basin to the Paraná river in the South of Brazil turned it into an invasive species in the new habitat, even though it never crossed the national borders. The same happens with *Mimosa caesalpiniiifolia*, native to the dry Caatinga ecosystem in north-eastern Brazil, used for hedges in other

ecosystems, and invasive especially in the Atlantic rain-forest. From a biological standpoint, it makes far more sense to prevent the movement of species between ecosystems or biogeographic regions than to keep a concern only with the transposition of national borders.

As a proportion of these alien introduced species manages to establish self-sustaining populations in the new range, they are called **established species**.

Finally, some of the established species are able to advance over natural or semi-natural environments, becoming **invasive**. According to the International Convention on Biological Diversity, an invasive species is "*an introduced species that advances without direct human assistance and threatens natural or semi-natural habitats outside its natural distribution range*", causing economic, social or environmental impacts.

These previous definitions draw a dynamic framework in the process of growth of an invasive species. In this sense, an introduced species can survive without harm for an unknown period of time until it is able to override certain environmental restrictions, reproduce and form a population, becoming established. With time this species can advance notably over natural environments, becoming invasive. This time frame depends on the species and on local conditions, not being predictable. The technical term for this period of time is "lag phase", referring to the time a species, under certain circumstances, needs to adapt, reproduce and spread. Therefore, it is important to note that to assess the situation of an invasive alien species one cannot consider only the present moment. There is always an evolutionary tendency for adaptation, establishment and invasion, especially if the species has a history of invasion elsewhere.

The main reason why biological invasions are currently

more obvious and produce wide-ranging impacts lies in the ease for trespassing natural barriers that formerly limited their dispersal. Human movement across the planet increased significantly with the advance of aerial, fluvial, maritime and road transport all over the world. These commercial routes also facilitate the transport of invasive species and are technically defined as **pathways**, which include roads, commercial routes and the ornamental, fishing, agriculture and forestry trades, among many others. The ways or materials through which species are transported are defined as **vectors**. For example, ballast water is the vector for the establishment of the golden mussel, *Limnoperma fortunei* in Argentina. Other vectors include ship and boat hulls, soil, animals, wood or other materials used for packaging, fishing or diving equipment, trash, machinery and vehicle tyres.

It is important to note that not all alien species become invasive and that impacts vary according to species and habitats. Still, some species cause serious impacts of wide-ranging consequences, especially if left uncontrolled. Invasive alien species, rated as the second cause of biodiversity loss in the planet, need to be treated under the precautionary principle advocated by the Convention on Biological Diversity.



**Dr. Sergio M. Zalba**

GEKKO, Grupo de Estudios en Conservación y Manejo  
Universidad Nacional del Sur  
Bahía Blanca, Argentina

### The Global Invasive Alien Species Issue

The spread of invasive alien species (IAS) is now recognised as one of the greatest threats to the ecological and economic well-being of the planet. These species are causing enormous damage to biodiversity and the valuable natural agricultural systems upon which we depend. Direct and indirect health effects are increasingly serious and the damage to nature is often irreversible. The effects are exacerbated by global change and chemical and physical disturbance to species and ecosystems.

Continuing globalisation, with increasing trade, travel, and transport of goods across borders, has brought tremendous benefits to many people. It has, however, also facilitated the spread of IAS with increasing negative impacts. The problem is global in scope and requires international cooperation to supplement the actions of governments, economic and public sectors and organisation at national and local levels.

Invasive species occur in all major taxonomic groups, including viruses, fungi, algae, mosses, ferns, higher plants, invertebrates, fish, amphibians, reptiles, birds and mammals. Even though only a small percentage of species that are moved across borders become invasive, these may have extensive impacts.

### Environmental costs

Invasive alien species can transform the structure and species composition of ecosystems by repressing or excluding native species, either directly by outcompeting them for resources or indirectly by changing the way nutrients are cycled through the system. IAS can affect entire systems: for example, when invasive insects threaten native species of insects, they can also have cascading effects on insect-eating birds and on plants that rely on insects for pollination or seed dispersal.

Increasing global domination by a few invasive species threatens to create a relatively homogeneous world rather than one characterised by great biological diversity and local distinctiveness.

No criteria have yet been agreed upon for the minimum damage, spread or size of population needed for an alien species to be considered invasive. However, it is clear that a very small number of individuals, representing a small fraction of the genetic variation of the species in its native range, can be enough to generate, through its reproduction and spread, massive environmental damage in a new environment.



*Thunbergia grandiflora* Photo: Silvia R. Ziller



Podranea ricasoliana Photo: Silvia R. Ziller



Leucaena leucoccephala Photo: Silvia R. Ziller



Black wattle Photo by Sue Matthews

# INTRODUCTION

Acacia mangium Photo: Silvia R. Ziller



## Economic costs

Invasive alien species have many negative impacts on human economic interests. Weeds reduce crop yields, increase control costs, and decrease water supply by degrading water catchment areas and freshwater ecosystems. Tourists unwittingly introduce alien plants into national parks, where they degrade protected ecosystems and drive up management costs. Pests and pathogens of crops, livestock and trees destroy plants outright, or reduce yields and increase pest control costs. The discharge of ballast water introduces harmful aquatic organisms, including diseases, bacteria and viruses, to both marine and freshwater ecosystems, thereby impacting commercially important fisheries. Recently spread disease organisms continue to kill or disable millions of people each year, with profound social and economic implications. GISP has not sought to estimate an aggregated economic cost of invasions globally, but one study for the USA estimates costs of \$137 billion per year from an array of invasive species

Considerable uncertainty remains about the total economic costs of invasions; however, estimates of the economic impacts on particular sectors indicate the seriousness of the problem. The varroa mite, a serious pest in honeybee hives, has recently invaded New Zealand and is expected to have **an economic cost of US\$267-602 million**, forcing beekeepers to alter the way they manage hives. Beekeepers argue that had border rules been

followed or had surveillance detected the mite earlier, the problem could have been avoided entirely. It now appears too late to eradicate the mite, requiring a mitigation plan that is expected to cost \$1.3 million in its first stage.

A 1992 report by the Weed Science Society of America estimated that the total **cost of invasive weeds was between \$4.5 billion and \$6.3 billion**. While the range of these figures indicates their uncertainty, they also reflect the order of magnitude of impact and argue for significant investments to prevent the spread and proliferation of these species.

In addition to the **direct costs** of management of invasives, the economic costs also include their **indirect environmental consequences and other non-market values**. For example, invasives may cause changes in ecological services by disturbing the operation of the hydrological cycle, including flood control and water supply, waste assimilation, recycling of nutrients, conservation and regeneration of soils, pollination of crops, and seed dispersal. Such services have both current use value and option value (the potential value of such services in the future). In the **South African Cape Floral Kingdom**, the establishment of invasive tree species decreases water supplies for nearby communities, increases fire hazards, and threatens native biodiversity, justifying government expenditures of **US\$40 million per year for physical and chemical control**.

Although the loss of crops due to weeds or other alien pests may be reflected in the market prices of agricultural commodities, such costs are seldom paid by the source of the introductions. Rather, these costs are negative externalities,







i.e., costs that an activity unintentionally imposes on another activity, without the latter being able to extract compensation for the damage received. One special feature of biological invasions, as externalities, is that the costs of invasions are largely self-perpetuating, once they are set in motion. Even if introduction ceases, damage from the invasives already established continues and may increase.

**Most evidence of economic impact of IAS comes from the developed world. However, there are strong indications that the developing world is experiencing similar, if not proportionally greater, losses.**

Invasive alien insect pests, such as the **white cassava mealybug and larger grain borer in Africa, pose direct threats to food security**. Invasive weeds constrain efforts to restore degraded land, regenerate forests and improve utilisation of water for irrigation and fisheries. Water hyacinth and other alien water weeds affecting water use currently **cost developing countries over US\$100 million annually**.

Furthermore, many introductions are unintentional, including most invertebrates and pathogens. Prices or markets cannot readily reflect the costs of these introductions. But even in the case of introductions involving deliberate imports to support agriculture, horticulture, forestry, and fisheries, market prices for seeds, plants, or foods do not

generally reflect the environmental risks associated with their use. Producers therefore have little financial incentive to take account of the potential cost of the loss of native species or disturbance to ecosystem functions. The policies developed to deal with conventional externalities involved in the general problem of biodiversity loss – such economic tools as taxes, subsidies, permits and so forth – may not always be well suited to deal with the problem caused by invasions. This highlights the urgency for new economic approaches to deal with IAS.

## Human health costs

The dynamism among invasive pathogens, human behaviour, and economic development are complex and depend on interactions between the virulence of the disease, infected and susceptible populations, the pattern of human settlements, and their level of development. **Large development projects**, such as dams, irrigation schemes, land reclamation, road construction and population resettlement programmes, have contributed to the invasion of **diseases such as malaria, dengue, schistosomiasis and trypanosomiasis**.

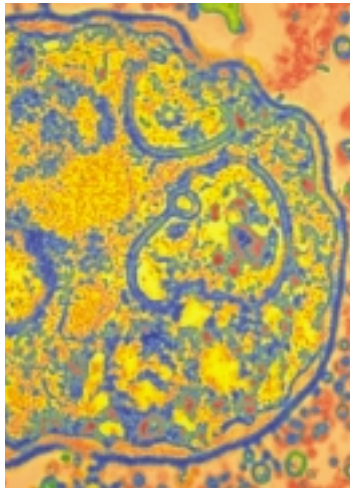
## INTRODUCTION



**The clearing of forests** in tropical regions to extend agricultural land has opened up new possibilities for wider transmission of viruses carrying haemorrhagic fevers that previously circulated benignly in wild animal hosts. Examples include Argentine haemorrhage fever, Guaranito virus, Machupo virus, and Basia virus. Some pathways for the biotic invasion are complicated. For example, the prevalence of **lymphatic filariasis in the southern Nile Delta** has increased 20-fold since the building of the Aswan dam in the 1960s. This expansion has been due primarily to the increase in breeding sites for the mosquito vector of the disease, following the rise in the **water table resulting from the extension of irrigation**. The problem has been exacerbated by increased pesticide resistance in the mosquitoes, due to heavy agricultural pesticide use and by rural-to-urban commuting among farm workers. Thus invasive species combined with variations in inter-annual rainfall, temperature, human population density, population mobility and pesticide use all contribute to one of the most profound challenges of invasive species: the threat to human health.

**Infectious disease agents often, and perhaps typically, are invasive alien species.** Unfamiliar types of infectious agents, either acquired by humans from domesticated or other animals, or imported inadvertently by travellers, can have devastating impacts on human populations. Pests and pathogens can also undermine local food and livestock production, causing hunger and famine.

**Indirect health affects** associated with IAS include the use of broad spectrum pesticides against invasive pests and weeds. Free from their natural controlling factors, these organisms often reach sustained outbreak levels that encourage widespread and chronic pesticide use.



AIDS virus

### Addressing the IAS issue

The spread of invasive alien species is creating complex and far-reaching challenges that threaten both the natural biological riches of the earth and the well-being of our people. While the problem is global, the nature and severity of the impacts on society, economic life, health, and natural heritage are distributed

unevenly across nations and regions.

Some aspects of the global IAS problem require solutions tailored to the specific values, needs, and priorities of nations while others call for consolidated action by the larger world community. Preventing the international movement of invasive alien species and coordinating a timely and effective response to invasions **requires cooperation and collaboration among governments, economic sectors, non-governmental organisations, and international treaty organisations.**

**At the national level,** consolidated and coordinated action is required. This could be part of a national biodiversity strategy and action plan, with close involvement



BIG-HEADED ANT Photo: www.mymecos.net



CHINESE WAX LEAVED PRIVET Photo: www.plante-arbustif.it

of the economic sectors and identifying people responsible for operative actions involving potential IAS as a key prerequisite. Clear responsibilities for each relevant sector would need to be identified.

**Insurance mechanisms and liability regulations** for the spread of IAS are almost non-existent, presenting a major deficiency for controlling the problem. Governments should therefore be encouraged to cooperate with the insurance sector to find solutions, beginning with feasibility studies.

Capacity and expertise to deal with IAS are not yet sufficient in many countries. Further **research and capacity building** around the biology and control of IAS and biosecurity issues therefore need to be given attention and priority. This also relates to financial institutions and other

organisations responsible for environment and development cooperation, at national and international levels.

**A global information system** regarding the biology and control of IAS is also required. Tools, mechanisms, best management practices, control techniques and resources need to be provided and exchanged. Such a proposed system is currently developed as part of the Global Invasive Species Information Network (GISIN) and is intended to link to the Clearing House Mechanism of the Convention on Biological Diversity.

**Awareness raising and education** regarding IAS should be given high priority in action plans, and development of economic tools and incentives for prevention are urgently needed.

## The Convention On Biological Diversity

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Numerous international instruments, binding and non-binding have been developed to deal with aspects related to the IAS issue. The most comprehensive is the Convention on Biological Diversity (CBD), which calls on its parties to “prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats, or species” (Article 8h).

The CBD was one of the main results of the UN Conference on Environment and Development, held in Rio de Janeiro in 1992. Entering into force in 1993, the CBD is today's largest environmental convention with 188 member countries.

The CBD commits governments to:

- take appropriate measures to conserve biological diversity
- ensure the sustainable use of biological resources, and
- promote the fair and equitable sharing of benefits arising from the utilisation of genetic resources.

Under the CBD, governments agree to:

- prepare national biodiversity strategies and action plans
- identify genomes, species, and ecosystems crucial for conservation and sustainable use
- monitor biodiversity and factors that are affecting biological systems
- establish effectively managed systems of protected areas
- rehabilitate degraded ecosystems
- exchange information
- conduct public information programmes, and
- various other activities for implementing the objectives of the CBD.

**The Subsidiary Body on Scientific Technical and Technological Advice (SBSTTA) of the CBD** meets periodically and addresses key issues, including invasive alien species (IAS). The CBD has also established an interim financial mechanism, the **Global Environment Facility (GEF)**, which provides in excess of US\$100 million per year to projects for implementing the Convention in developing countries. (<http://www.biodiv.org>)

[www.biodiv.org](http://www.biodiv.org)

# The Global Invasive Species Programme – GISP

**The GISP mission is to conserve biodiversity and sustain human livelihoods by minimising the spread and impact of invasive alien species (IAS).**

GISP is a partnership programme consisting of GISP Members, a Board, a Secretariat and a variety of international, regional and national partner organisations. The programme is intended to create synergy, not only among the work programmes of its members, their regional offices and centres, but also with a wide range of global partners.

The GISP Founding Members include

- The World Conservation Union (also known as IUCN –The International Union for Conservation of Nature and Natural Resources)
- CAB International (CABI)
- The Nature Conservancy (TNC)
- South African National Biodiversity Institute (SANBI).

SANBI has also agreed to host the voluntary association, and provide administrative and logistical support to the GISP Secretariat, which is located at the SANBI offices in Kirstenbosch Gardens.

## **GISP Constitutional Objectives**

The primary objective of GISP is to facilitate and assist with the prevention, control and management of invasive species throughout the world.

To achieve this, GISP will:

1. raise global awareness of the ecological and socio-economic impacts of invasive species
2. contribute to the development of a global information system on invasive species and maintain a website to facilitate information exchange
3. gather, assess and disseminate information on the impacts of invasive species, the resources and methods available for preventing incursions and for the control and management thereof once they have been introduced
4. improve the technical basis for assessing the impacts of invasive species and for their prevention, control and management
5. build capacity to deal with invasive species by providing information, advice and training to entities and officials who have been tasked with the management of invasive species
6. inform policy development, both on a multilateral and on a national level
7. build international partnerships and networks to achieve the various objects set out above.



# SOUTH AMERICA invaded

## A GISP Publication

This publication is a product of the GISP Secretariat, established in South Africa in June 2003, with the generous input from numerous South American and other IAS specialists, organisations and governments. It is designed to be part of a comprehensive series of similar publications, focusing on various regions, continents and / or specific ecosystems around the world, with a strong focus on the developing world. Further, it should be seen as part of a wider awareness raising and information programme within GISP, complementing other GISP projects and documents like the GISP Global Strategy and the GISP toolkit, both available in various languages from the GISP website ([www.gisp.org](http://www.gisp.org)).

The publication aims to raise general awareness in South America and elsewhere about some of the more prominent IAS issues facing the continent today. It is not a technical document, but rather aims to demonstrate the diversity of the IAS issue to a broad audience, including decision and policy makers, government departments and the general public. Focusing not on a list of top invaders, but rather showcasing diverse species, affecting different ecosystems and regions within South America, it only highlights a small percentage of the IAS invading South America today. What becomes evident is that the IAS issue in South America is enormous both in terms of the number and diverse range of species invading the continent, and of their impact on the health and livelihoods of all peoples of the region.

Addressing the IAS issue in South America clearly requires both national and international action, and it is the goal of GISP to assist the region in raising awareness of this pressing need.

For more on the GISP publications, programmes and educational material, visit us at [www.gisp.org](http://www.gisp.org) or contact us at tel: +27 (21) 799 8836 or fax: +27 (21) 797 1561 or email at: [gisp@sanbi.org](mailto:gisp@sanbi.org)

## TREES



For centuries, species of trees have been translocated from their original habitats to other countries, or even to new regions within the same country. This movement was typically motivated by their value as a source of fruit, pulp, wood, tannins and traditional medicines, or for their use as windbreaks or ornamentals.

Unfortunately, the same characteristics that are prized in terms of productivity – such as short maturation period, early seeding, rapid growth and competitive vigor – are also those that contribute to the species' invasive potential. In each case a comprehensive risk analysis should be conducted to ensure that the benefits of introducing a species for cultivation will not be outweighed by its negative impacts. For example, neem *Azadirachta indica* is being widely promoted as an agroforestry tree in South America, as the seeds contain compounds that can be used in the production of natural, 'environmentally friendly' pesticides. However, the species has proved to be highly invasive in other parts of the world where it has been introduced. In Ghana in West Africa, agricultural

losses and environmental impacts apparently exceed any benefits accrued.

Introduced species that have become invasive in South America include, among countless others, ornamental trees such as African tulip tree *Spathodea campanulata* – the flowers of which are toxic to small birds – and fruit trees such as the mango *Mangifera indica*, which is native to south Asia but invading riparian areas in the arid north-east region of Brazil. A few key species are highlighted on the following pages.



Leucaena leucocephala. Photo: Silvia R. Ziller

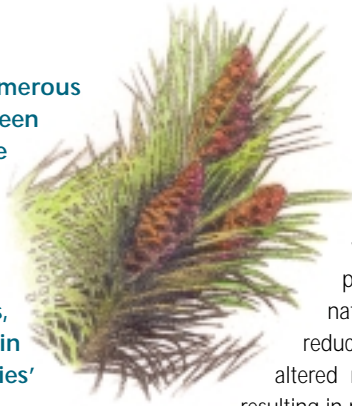


MANGO Photo: www.hear.org



NEEM *Azadirachta indica* Photo: <http://members.chello.be>

Since the 19th Century, numerous species of pine *Pinus* spp. have been introduced to countries in the southern hemisphere, mainly for forestry purposes. Those found to be the best adapted and most productive in each habitat were used to establish plantations, and governments put initiatives in place to develop their countries' pulp, paper and wood industries.



### A variety of species

Today, various species of pine are invasive in most countries where the genus was introduced, including those in South America. Species causing the greatest problems are those established long ago and over vast areas, since these have had more time and habitat diversity in which to adapt to their new environments. The impacts of invasive pines are especially evident in open ecosystems such as grasslands and savannas, where they reduce runoff, lower the water table, displace native species, modify the landscape, increase the risk of fire, and prevent the regeneration of natural habitats.

In Brazil, the southern grasslands, coastal sand dune vegetation, savannas and many deforested areas are highly threatened by the invasion of pines, mainly *P. elliotii* and *P. taeda*. In Argentina, several species – among them *P. radiata* and *P. halepensis* – have successfully invaded areas of high biodiversity value in the pampas region, the Andean-Patagonia forest, the Patagonia steppe and the north-eastern forests. Observed impacts include changes in soil properties, as well as in the composition of plant, bird and invertebrate communities. In Uruguay, *P. pinaster* was introduced for sand stabilisation, but has become invasive

in coastal dune vegetation in the south and south-east of the country. In Colombia, there are an estimated 52 000 hectares of forestry plantation, dominated by *P. patula* and concentrated in the Andean region, where the species was initially planted in protected areas. Its invasion has displaced native species, changed succession patterns and reduced structural diversity of plant communities, altered nutrient cycling, and increased fuel loads, resulting in more frequent and intense fires. In Venezuela, the most common species used for forestry is *P. caribaea*. More than 20 species of pine have been introduced to Chile, but *P. radiata* is the dominant species, comprising more than 1.5 million hectares of plantation. Although this is one of the most aggressive pine species in the southern hemisphere, its status as an invader is still being debated in Chile.

While the significance of pines in South American economies is recognised, it is important to ensure that forestry production is compatible with the need for environmental protection and biodiversity conservation. The location of plantations should be carefully planned, and management should be improved to prevent the spread of pines beyond cultivated areas, with criteria established for distributing seedlings for ornamental or windbreak purposes. Control actions should be considered where pines have invaded natural systems, particularly in protected areas. Indeed, control of plantation 'escapees' is common practice in countries such as New Zealand and South Africa.

Control can be achieved by mechanical methods alone, as pines do not resprout if felled close to the ground. Ringbarking is another effective – if slow – method of killing trees, while small seedlings can be uprooted by hand when the soil is moist.

Photo: www.hear.org

In 1995, the total estimated area of forest plantations in South America was 8.2 million hectares. Three countries accounted for 82% of this resource: Brazil (with 4.2 million hectares), Chile (1.7 million hectares) and Argentina (0.8 million hectares). However, large areas of forest plantations can be found throughout the continent, with 8 of the other 13 countries having more than 0.1 million hectares of forest plantations each.

The total area of forest plantation planted with *Pinus* species was about 3.5 million hectares



*Eucalyptus robusta*

in 1995. However, *Eucalyptus* species accounted for about 3.9 million hectares, being the most commonly used species in the tropical and subtropical parts of the continent. They account for 65% of the forest plantation area in Brazil, 90% in Peru and 80% in Uruguay. Some species – such as *Eucalyptus robusta* in

Brazil and *Eucalyptus camaldulensis* in Argentina – have escaped from plantations and become invasive.

Source: Brown, C. 2000. *The global outlook for future wood supply from forest plantations*. FAO Working Paper No: GFPOS/WP/03



Escapes: from pine plantation. Photo: Silvia R. Ziller



Control of *Pinus halepensis* in Argentina. Photo by Sergio M. Zalba

*Pinus elliotii* Photo: www.forestryimages.org



*Pinus caribaea* Photo: www.virtualherbarium.org



*Pinus patula* Photo: www.cuyamaca.net



*Pinus pinaster* www.komsta.net



*Pinus radiata* Photo: www.hear.org



*Pinus halepensis* Photo: http://personales.ya.com

BLACK WATTLE. Photo: Silvia R. Ziller



**The genus *Acacia* comprises some 1 500 species, and almost 1 000 of these are indigenous to Australia, where they are commonly known as wattles. Many species have been introduced and become invasive in other parts of the world, with a variety of negative consequences.**

Most importantly, invasive acacias cause a loss of biodiversity by outcompeting indigenous species and disrupting natural ecosystem functioning. Acacias are nitrogen-fixing plants that increase nitrate levels in the soil, and since many indigenous species cannot survive in enriched soils, the alien invaders soon form uniform monocultures.

Dense stands of acacias may reduce the productive potential of land by taking over agriculturally valuable areas, and heighten the risk and intensity of fire by increasing the fuel load. Very hot fires destroy the seeds of indigenous species, compromising post-fire regeneration.

Alien acacias often have higher water requirements than the indigenous vegetation they replace, so infestations in catchment areas and along watercourses may reduce runoff and hence river flow. This not only has detrimental impacts on riverine and wetland ecosystems, but ultimately translates to less water in dams for agricultural, industrial and domestic use. Impenetrable thickets along watercourses block access of people and livestock to water, and obstruct the flow of rivers – particularly during floods, when fallen trees create logjams and blockages that cause further flood damage. The absence of groundcover in acacia thickets may also result in increased soil erosion.

Acacias produce large quantities of seeds that are widely dispersed by birds and wind. The seeds germinate readily in a variety of different environments, but can also remain viable in the soil for long periods.

A few of the invasive acacias in South America are highlighted below.

### **Black wattle**

The black wattle *A. mearnsii* is an Australian evergreen tree that is often grown as an ornamental species. However, it is also commercially cultivated in many countries for its tannin-rich bark, which is used in the leather industry, and for its timber – a source of woodchips, firewood and building material. Unfortunately, the species has spread from plantations and is considered invasive in South Africa, Tanzania, Reunion, the United States (Hawaii and California) and a number of Mediterranean countries. It typically invades chaparral, grasslands, forest gaps, roadsides and watercourses.

Commercial cultivation is expanding in a number of South American countries. In Brazil, for example, black wattle has been widely promoted as a source of tannin and firewood, but there are no regulations or control measures in place to prevent its spread. In Argentina, the species is invading the mountain areas of the pampas, and control measures have been initiated in recent years.



BLACK WATTLE Photo: Sue Matthews

Black wattle is a vigorous resprouter, so felled trees will coppice unless the stump is treated or the entire plant is removed. Large trees are usually felled as close to the ground as possible, and the stump treated with a registered herbicide. Seedlings and saplings can be pulled out by hand when the soil is damp, but chemical control is often preferable if growth is very dense, as large-scale uprooting results in soil disturbance, that promotes the germination of wattle seeds. However, it is important that selective herbicides are used where grasses are present, and that diesel-based herbicides are not used along water-courses, so as to avoid contaminating the water.

### Mangium wattle

The mangium wattle *A. mangium* is an evergreen tree that is native to Australia, Papua New Guinea, Indonesia and the Molluccan Islands. It has been planted in many humid tropical regions as a source of paper pulp, fuelwood, construction timber, furniture wood, and also for erosion control.

In South America it has been introduced primarily as a forestry species, but has sometimes been used in land rehabilitation projects, and is often seen in urban areas. In Colombia and Venezuela, it is also being promoted as a source of forage for cattle. In some regions, however, the species has invaded coastal dune vegetation, wetlands, grasslands and forest ecosystems. In Brazil, for example, it is invasive in the states of Amapa and Roraima in the Amazon region, as well as in the Atlantic Forest and coastal vegetation in Bahia, Espírito Santo and Rio de Janeiro.

MANGIUM WATTLE Photo: [www.nparks.gov.sg](http://www.nparks.gov.sg)



### Long-leaved wattle

The long-leaved wattle *A. longifolia* was introduced from Australia to South America, as well as many other regions, primarily for dune stabilisation. It is now advancing along the coast of northern Argentina, Uruguay and southern Brazil.

The species can also invade other habitats, however. In South Africa, for example, it spread rapidly along dry mountain slopes and rivers in the fynbos biome, and also invaded forest and grassland habitats. It was considered a major threat to biodiversity until it was successfully brought under biological control. This has been achieved with two biocontrol agents – the bud-galling wasp *Trichilogaster acaciaelongifoliae* and the acacia seed weevil *Melanterius ventralis* – that reduce both the rate of invasion and the density of existing infestations.

Other introduced acacias in South America include, among others:

- The silver wattle *A. dealbata*, a frost-tolerant species that has become naturalised in Chile and Argentina
- The Australian blackwood *A. melanoxylon*, introduced throughout the continent and valued as an ornamental and forestry species – particularly as a source of wood for furniture – but a threat to relic native grasslands in the pampas of Argentina and Chile
- The green wattle *A. decurrens*, found in the states of Cundinamarca, Huila and Antioquia in Colombia and along the continental coast of Venezuela
- The white or oleander wattle *A. nerifolia*, introduced as an ornamental species to Venezuela, where it is found in urban areas
- The prickly acacia *A. nilotica*, a species complex that is indigenous to Africa and the Middle East but occurs on Ecuador's Galapagos Islands.

SILVER WATTLE Photo: [www.abc.net.au](http://www.abc.net.au)

GREEN WATTLE Photo: [www.rakuten.co.jp](http://www.rakuten.co.jp)

LONG-LEAVED WATTLE Photo: [www.tropengarten.de](http://www.tropengarten.de)



PRICKLY ACACIA Photo: [www.virtualherbarium.org](http://www.virtualherbarium.org)

## TREES CHINABERRY

The chinaberry *Melia azedarach* – also known as the syringa, cinamomo or paraíso – is native to south-east Asia. It has been introduced to many countries as an ornamental and shade tree, and is often found lining city streets. Chinaberry thrives in tropical climates but also tolerates low-rainfall areas (600-1000 mm). It has become invasive in South Africa, several Pacific islands and southern states in the USA, as well as most of South America.

The species occurs in all the continent's countries, but is only invasive in suitable habitats. For example, although it is common in the southern pampas, it is not invasive in grasslands, which grow on sandy soils. It seems to prefer clay soils and riparian areas, and is an aggressive invader in subtropical forest along rivers in both Uruguay and south-western Brazil. In Argentina the species has advanced over the humid mountain forests ('yungas') and invaded El Palmar National Park, where a comprehensive control strategy has been implemented.

Chinaberry seeds are dispersed by birds and bats, which eat the berries. The seeds can be toxic to pigs, however, and can cause nausea and seizures in humans. The tree is valued for its medicinal properties in some areas though. In Ecuadorian Amazonia, for example, members of the Quichua tribe eat the cooked leaves to relieve headaches. In Surinam, leaf extract is used to treat scabies or itches, while in French Guiana it is used to make a gargle for treating tooth and gum problems.

Chinaberry should be gradually replaced in regions where it is invasive by native species, or at least non-invasive exotics. Riparian areas are priority targets for control to protect ecosystem functioning, water balance and biodiversity. Trees resprout vigorously when cut, so physical control will only be successful if used in conjunction with chemical control. Oil-based triclopyr herbicides are effective when used as a cut-stump or basal-bark treatment, but less so as a foliar spray.



Photo: [www.plante-arbusli.it](http://www.plante-arbusli.it)



Photo: [www.bharian.com.my](http://www.bharian.com.my)

## TREES JAPANESE CHERRY

The Japanese cherry or raisin tree *Hovenia dulcis* is native to Japan, China and Korea. It was introduced to a number of South American countries for ornamental, windbreak and forestry purposes, and became a commonly cultivated tree in gardens and city streets. More recently it has been used for honey production in the south of Brazil. The fruits attract birds and other animals, which help to spread the plant by dispersing the seeds.



Photo: www.tropicamente.it

The Japanese cherry has become extremely invasive in forest ecosystems in moist climates, and is one of the major threats to biodiversity in the Uruguay River basin shared by Brazil, Argentina, Uruguay and Paraguay. By displacing native forest species it alters the food chain, creating ripple effects throughout the forest community and ultimately leading to a reduction in biodiversity.

The tree quickly becomes dominant if left uncontrolled, but control efforts are complicated by the fact that it sprouts vigorously if cut, and regenerates from the soil seedbank. The use of appropriate herbicides and ongoing follow-up work is therefore necessary.



## TREES LOQUAT



Photo: www.floridata.com

The loquat *Eriobotrya japonica* is native to south-east China, but has been widely introduced elsewhere for its fleshy fruit. It is a popular garden plant, and is commercially cultivated in a number of countries, with China and Japan dominating the world market. The fruit are also relished by birds and other animals, which disperse the

seeds in their faeces. This has facilitated the spread of the species, and in some places it has become invasive, including South Africa, New Zealand, Hawaii, and parts of South America.

In Brazil, where it is known as 'nêspera', loquat can be seen in the garden of nearly every home in some southern cities, and has spread to forests nearby. In Argentina, the tree is invasive in the 'yungas' – the humid mountain forests of extremely high conservation value in the north-west of the country. In Venezuela, loquat is mainly found in urban areas, but also occurs in natural areas, including the Avila National Park straddling the Cordillera de la Costa mountain range.

Loquat would be difficult to eradicate as it is so widely cultivated, so the focus is usually on controlling it in natural and protected areas. Physical control alone is ineffective as the plant resprouts if cut, but successful results have been achieved using triclopyr ester as a cut-stump or basal-bark treatment.

## TREES AFRICAN OIL PALM

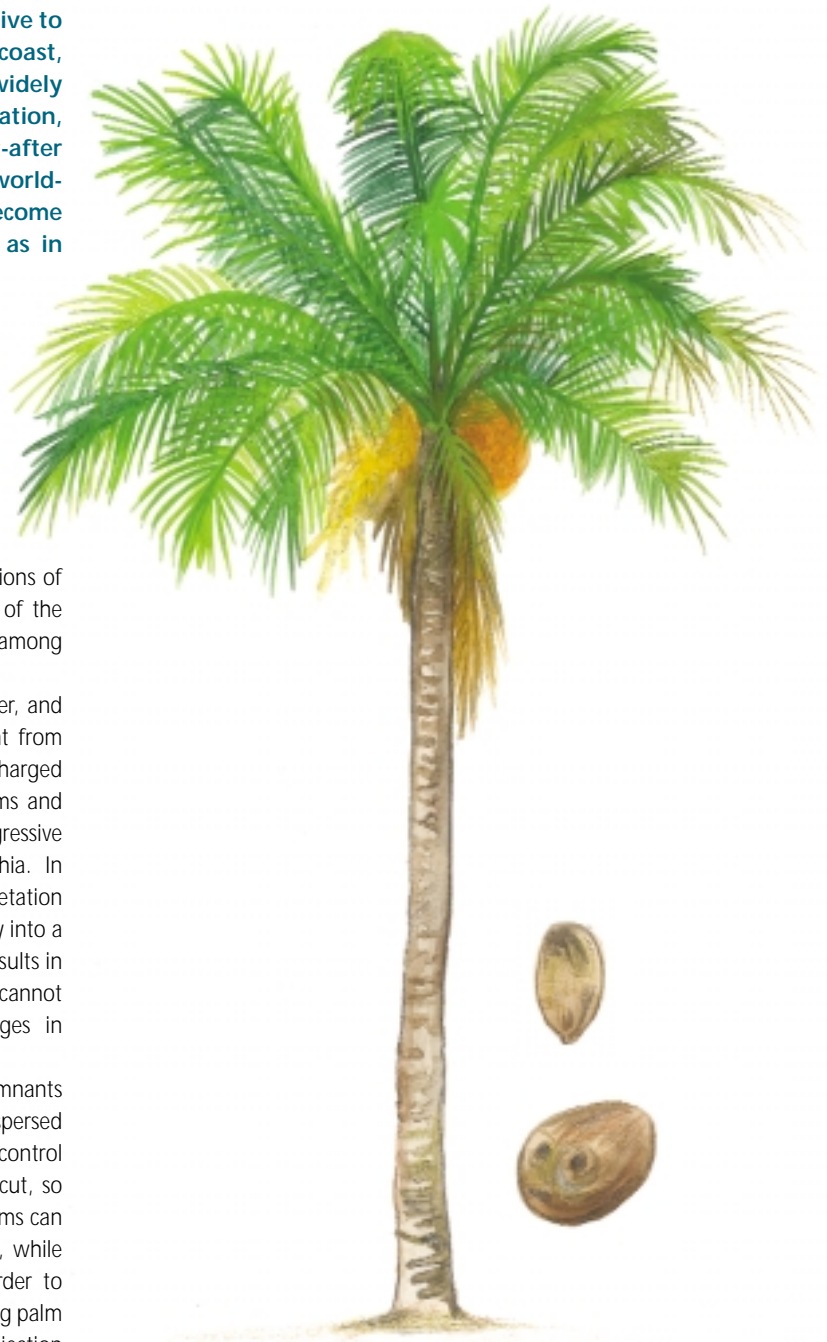
The African oil palm *Elaeis guineensis* is native to the tropical forests of the West African coast, where it favours riparian areas. It was widely introduced to tropical regions for cultivation, and commercial production for its sought-after oil now occurs in more than 40 countries worldwide. Unfortunately, the species has become invasive on many Pacific islands, as well as in parts of South America.

### Benefits and costs

The African oil palm was first introduced to South America by Portuguese and Spanish colonists during the 1500s, and the oil remains a distinctive ingredient in the traditional cuisine of north-eastern Brazil, particularly in the state of Bahia. Much later – starting in about the 1950s – plantations of African oil palm were established in various parts of the continent, and today Colombia and Ecuador are among the world's top 10 producers of palm oil.

The plantations reduce natural habitat, however, and displace native species of flora and fauna. Effluent from the oil-processing plants is sometimes also discharged without adequate treatment, polluting local streams and rivers. Furthermore, the oil palm has become an aggressive invader of the Atlantic Forest ecosystem in Bahia. In riparian areas it has been replacing the natural vegetation to the point of dominance, transforming the canopy into a homogeneous layer of palm leaves. This not only results in loss of habitat, but also compromises animals that cannot exploit the new food source, leading to changes in community structure.

Control of African oil palm is necessary if the remnants of native forests are to be spared. The seeds are dispersed by mammals and large birds, which complicates control efforts. However, the species does not resprout if cut, so mechanical control methods are effective. Small palms can be killed by destruction of the apical growth bud, while large specimens can be felled. Alternatively, in order to avoid damage to surrounding native species by falling palm trees, glyphosate can be administered as a stem-injection treatment, which will kill the tree within a few months.



Tamarisks or salt cedars *Tamarix* spp. are native to Asia, North Africa and south-eastern Europe, but have become highly invasive in the United States, Mexico and Australia after being introduced for ornamental purposes, wind-breaks and erosion control. In South America, some species have become established in arid and semi-arid regions of Argentina and Peru, as well as parts of the southern coasts of Brazil and Uruguay. This is a matter of great concern, given the invasion history of the genus elsewhere.

In the United States, for example, about ten species of tamarisks were introduced at the beginning of the 19th century. In the 1920s, *T. ramosissima* invaded valleys of fast-flowing rivers and was recognised as a pest species. By 1950 it had invaded larger watercourses and lakes, from sea-level to an altitude of 2 500 m. It occupied an estimated 650 000 hectares in 23 states, and had become the most abundant species in riparian areas of the south-east.

### Fire and salt

Tamarisks have a number of characteristics that make them highly successful invaders. They can survive in a wide variety of habitats, and are able to tolerate saline soils and drought conditions. Their roots reach down to deep water tables, while their leaves store excess salt until they are shed. As the leaves accumulate on the ground below, they increase the salinity of the soil, impeding the germination and growth of native species. In addition, the fallen leaf material is highly flammable, so it increases the frequency of fire. This gives tamarisks a competitive advantage, as they are able to resprout more successfully than native plants after fire. They also have a remarkable reproductive capacity, each plant being able to produce more than half a million seeds per year. The seeds germinate readily in moist soil and



*Tamarix gallica* Photo: www.jtosti.com

young plants grow rapidly, exceeding 30 cm per year.

Invasion by tamarisks causes profound changes in water dynamics and the biotic community. By establishing along riverbanks, they frequently obstruct watercourses and promote flooding. Mature groves transpire large volumes of water, which can lower the water table beyond the reach of native species. Over time, the desertification and salinisation of invaded areas

results in the local extinction of native plant species, and their replacement by monospecific stands of tamarisks. Once dominant, tamarisks seem to completely control ecosystem-level processes, and re-establishment of native vegetation is inhibited.

### Control strategies

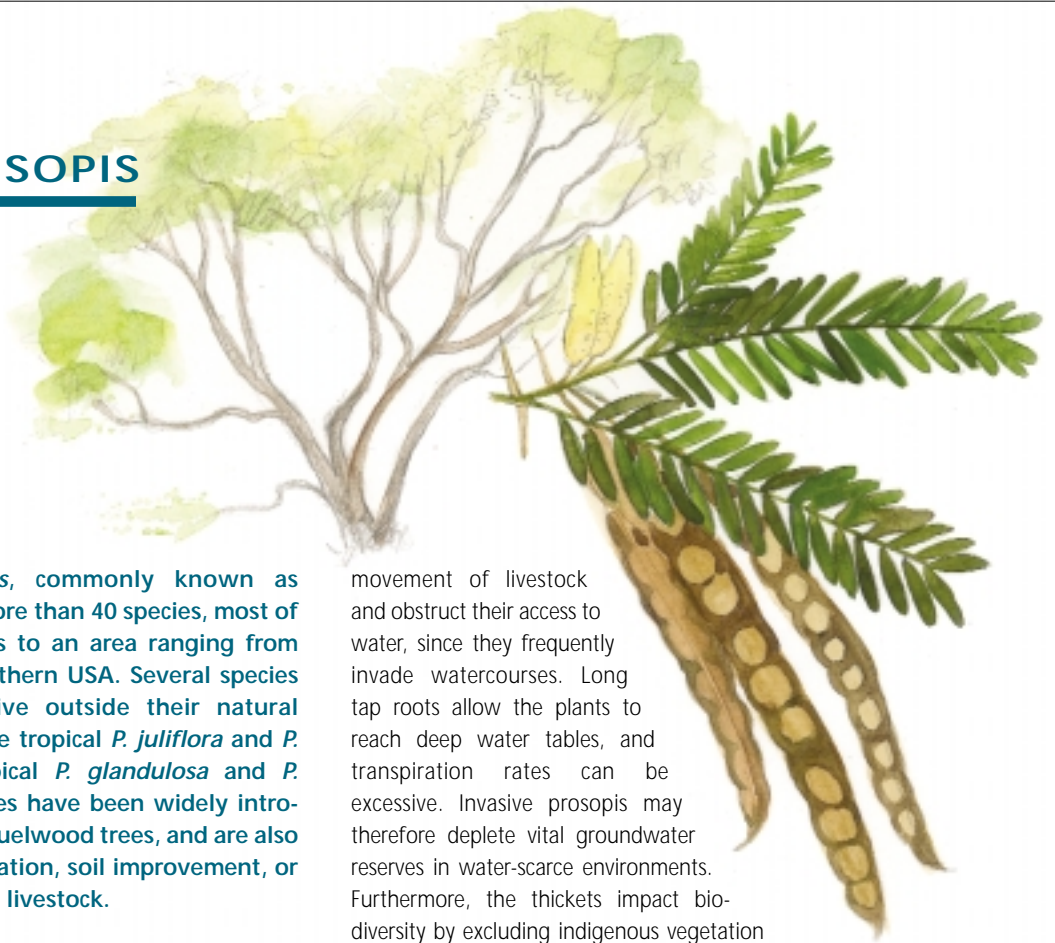
To date, three species of tamarisks have been detected in natural areas in Argentina: *T. gallica*, *T. ramosissima* and *T. chinensis*. The areas invaded include four National Parks – Las Quijadas, San Guillermo, Tlampaya and El Leoncito – as well as a Ramsar wetland, the Llanquanelo Lagoon. All are considered high-value areas for the conservation of native biodiversity, making them priority targets for control action.

Small invasions of tamarisks can be controlled with conventional mechanical and chemical methods, most commonly employing basal-bark or cut-stump treatment using triclopyr or imazapyr for infestations smaller than two hectares. Control of larger infestations is considered very difficult and expensive, and the potential for re-invasion is high. Most success is achieved with foliar application of imazapyr, sometimes used in combination with glyphosate. Aerial spraying is effective for vast, monospecific stands, but should not be conducted if biocontrol agents are present. The salt cedar leaf beetle *Diorhabda elongate* has been released in some states in the USA, and other biocontrol agents are under investigation.



*Tamarix chinensis* at El Chocón reservoir, Patagonia in Argentina. Photo by John F. Gaskin

## TREES PROSOPIS



The genus *Prosopis*, commonly known as mesquite, includes more than 40 species, most of which are indigenous to an area ranging from Argentina to the southern USA. Several species have become invasive outside their natural range, particularly the tropical *P. juliflora* and *P. pallida* and sub-tropical *P. glandulosa* and *P. velutina*. These species have been widely introduced as forage and fuelwood trees, and are also used for sand stabilisation, soil improvement, or for hedges to contain livestock.

### Fast-growing fodder source

Prosopis are fast-growing, nitrogen-fixing trees that are tolerant of arid conditions and saline soils. They are valued as a source of fodder because they remain green all year round, and the seed pods are a nutritious food for livestock when ripe. However, green pods are bitter and can poison livestock in large quantities, while the foliage is unpalatable due to the high tannin content.

Although individual prosopis occur as small trees, invading populations tend to form dense, impenetrable thickets made up of shrubby, multi-stemmed plants that provide minimal shade and produce fewer pods. The thickets reduce grass cover, so they limit natural grazing and hence stocking density. They may also restrict the

movement of livestock and obstruct their access to water, since they frequently invade watercourses. Long tap roots allow the plants to reach deep water tables, and transpiration rates can be excessive. Invasive prosopis may therefore deplete vital groundwater reserves in water-scarce environments. Furthermore, the thickets impact biodiversity by excluding indigenous vegetation and associated animal life.

The success of prosopis species as invaders is largely attributable to the massive number of seeds produced – about 60 million per hectare per year – and their efficient dispersal. Some seeds are carried far from their source by flowing water, especially during floods, but on a more local scale livestock and wild animals disperse the seeds after feeding on the pods. The hard-coated seeds are softened during their passage through the digestive tract, which enhances their germination, while the animals' droppings provide a ready supply of nutrients for the developing seedling. If the seeds fail to germinate immediately they may lie dormant in the soil for up to 10 years. Destruction of surrounding vegetation and exposure of the soil often stimulates mass germination of the soil seedbank, resulting in a sudden infestation.



*Prosopis pallida* Photo: [www.botany.hawaii.edu](http://www.botany.hawaii.edu)



## A managed approach

Prosopis is considered a valuable asset in many arid regions of South America, where few other trees could survive, so its eradication is generally not an option. A possible solution to the conflict of interests surrounding prosopis is to control invasive populations and manage them as agroforestry plantations. Apart from providing fodder and fuelwood, prosopis trees may yield hard and durable timber that can be used to make furniture and parquet flooring, while the protein-rich pods can be used in the manufacture of various food products. Unfortunately, the shrubby, multi-stemmed plants typical of invasive thickets generally only yield small pieces of lower-quality wood, with a large amount of wastage. Nevertheless, the wood may be suitable for making handles for appliances, brushes and tools, as well as charcoal and wood chip products.



Control of prosopis is especially difficult because the plants can regrow from vegetative buds just below ground level. These buds sprout new shoots if the aboveground parts of the plant are damaged, with the result that a small shrub may become a dense bush if attempts at control are inefficient. The plants are therefore usually felled close to the ground, preferably below the point of branching, after which an appropriate registered herbicide is sprayed on the cut surface. Prosopis is sometimes controlled with herbicides alone, using basal-bark treatment for mature plants and foliar spray for seedlings.

Two biocontrol agents – *Algarobius prosopis* and *Neltumius arizonensis* – have been introduced in some parts of the world for prosopis control. Both are seed-feeding beetles that reduce the invasiveness of prosopis plants, without affecting their useful attributes. A number of fungi that infect prosopis are also being investigated, to assess their potential for development as mycoherbicides.

The native range of *Prosopis pallida* extends from southern Peru to Ecuador and southern Colombia. However, the species is highly invasive in the north-east of Brazil, especially along watercourses in the semi-arid Caatinga region. It has also become naturalised – and is in places considered a noxious weed – in Australia, South Africa, Cape Verde, Senegal and Mauritania.



## ‘Miracle tree’ or menace?

*Leucaena leucocephala* is another tree species that has been promoted by international agroforestry organisations as a fodder and firewood resource, but is widely denigrated as a weed. Called the ‘miracle tree’ in the early years of its global cultivation, leucaena is a fast-growing, nitrogen-fixing and drought-tolerant tree that is native to Mexico and central America. It now occurs in most sub-tropical and tropical parts of the world, and in places provides a nutritional food source for livestock. However, both the foliage and seeds contain the amino acid mimosine, which can be toxic in large quantities.

Leucaena tends to invade forest margins, roadsides, wasteland, riverbanks and sometimes also cultivated land, forming dense thickets that are difficult to eradicate because the plant resprouts vigorously after cutting. It is widespread in South America, having been introduced to most countries on the continent. The species is listed as a weed in Argentina, Bolivia and Brazil, where it is particularly problematic in the Fernando de Noronha islands off the north-eastern coast.



## SHRUBS

Shrubs have typically been introduced beyond their natural range for ornamental purposes, often for use as hedge plants. Some have been introduced as sand stabilisers in erosion control projects, or as food plants – many yield berries that are eaten as fresh or stewed fruit or used to make jams and tarts. Being much-branched and multi-stemmed woody plants, invasive shrubs tend to form dense thickets, and are frequently more difficult to control than tree species.

### SHRUBS CASTOR OIL PLANT

The castor oil plant *Ricinus communis* is thought to be native to tropical Africa, but now has a global distribution, after being widely introduced as a garden ornamental. It is very variable in appearance – occurring as a shrub or small tree up to 4 m high – and has large star-shaped leaves. The fruits are covered with soft spines and are divided into three chambers, each containing a bean-like seed. In some regions the seeds are used to make necklaces, but it is the pale yellow oil inside the seeds for which the plant is most valued.

Castor oil is still used in traditional medicine as a purgative, but its more widespread use is in the manufacture of cosmetics, lubricants, plastics, paints, glues and dyes, among a wide variety of technical applications. As a result, the plant has been commercially cultivated in many countries. In Brazil – currently the world's third largest producer after India and China – it is even being promoted as a potential source of environmentally friendly fuel. Ecuador and Paraguay also contribute to the global market for castor oil, but the plant is common throughout much of South America, even in countries where it is not commercially cultivated.

#### Weedy pioneer

The castor oil plant is a pioneer species that tends to invade disturbed habitats, particularly roadsides, wastelands, riverbanks and agricultural lands. It is sometimes a nuisance in perennial crops such as sugarcane, and it frequently outcompetes and replaces indigenous vegetation along watercourses. Apart from its impact on biodiversity, the plant is also a threat to humans and animals, although it is not normally grazed by livestock. The entire plant is poisonous, but the seeds are lethally so, as they contain the potent toxin ricin. Chewing one seed is enough to kill a child, while two or three are deadly for an adult.

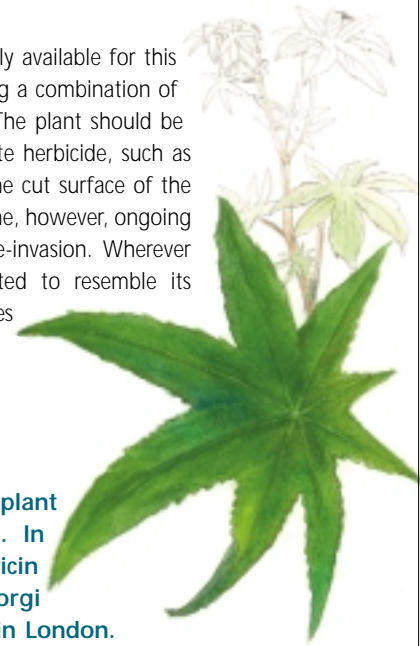
The plant's success as an invader is due to the effective dispersal of its seeds by birds, which eat the fruits and pass the seeds through their digestive systems with no ill effect, and by water, which transports the seeds downstream.

No biocontrol agents are currently available for this species, but it can be controlled using a combination of mechanical and chemical methods. The plant should be felled, following which an appropriate herbicide, such as Imazapyr SL, should be applied to the cut surface of the stump. As with any control programme, however, ongoing follow-up work is vital to prevent re-invasion. Wherever possible, land should be rehabilitated to resemble its natural state so that ecological processes are maintained.

#### BIOLOGICAL WARFARE

The seeds of the castor oil plant contain ricin, a potent toxin. In 1978, communist agents used ricin to assassinate journalist Georgi Markov, a Bulgarian defector, in London. The toxin was administered in a perforated metal pellet, which was apparently jabbed into his thigh from the tip of an umbrella while he waited for a bus.

More recently, in January 2003, British police raided an apartment in London and arrested nine people on charges of manufacturing ricin for the purposes of terrorism. Press reports at the time claimed that the men – mostly from Algeria – were part of an Al Qaeda plot to poison hundreds of people by contaminating food supplies with ricin or smearing it onto door handles. The British government used the incident – and the perceived threat to its citizens – to justify the 'war on terror' and its actions in Iraq. However, in April 2005, when the court case finally came to a conclusion, all were acquitted of terrorist conspiracy charges. Only one of the nine was sentenced to imprisonment, and that was for fatally stabbing a police officer during his arrest and conspiring to cause a 'public nuisance'. Evidently, the lab reports had been inaccurate, and no ricin had in fact been detected in the apartment.



## SHRUBS PRIVETS

JAPANESE PRIVET Photo: <http://cricket.biol.sc.edu>



Privets *Ligustrum* spp. are shrubs or small trees that are members of the olive family Oleaceae. There are about 50 species, most of which are native to Asia. Some common examples are the Japanese wax-leaved privet *L. japonicum*, the Chinese wax-leaved privet *L. lucidum*, the Chinese privet *L. sinense* and the European or common privet *L. vulgare*.

Privets have been widely introduced for ornamental purposes, and are particularly popular as hedge plants and street trees. Being highly adaptable species, however, they often become invasive. In South America they have been recorded from natural habitats in a number of countries, including Brazil, Argentina, Bolivia, Paraguay, Uruguay, Ecuador and Venezuela. They prefer damp habitats and disturbed sites, so are often found in wetlands, moist forests and shrublands, roadsides and degraded farmland. In Brazil, they are particularly problematic in the Araucaria temperate forests in the south of the country. In Argentina, *L. lucidum* is the most abundant exotic tree in secondary forest patches of the montane 'yungas' in the north-west,



and is also invasive in riparian forests in the south-eastern parts of the country.

Privets bear small dark fruits that are harmful to humans – causing nausea and headaches, low blood pressure and hypothermia if eaten – but are attractive to birds. They consume the fruits with no ill-effect and disperse the seeds, often excreting them in natural areas. In invaded habitats, privets can form dense thickets that outcompete native vegetation. They quickly dominate the understorey layer of shrubs in forests and shade out the herbaceous plants below, changing species composition and community structure.

Effective control requires the use of chemicals to prevent resprouting, and is usually achieved with triclopyr-based herbicides applied in oil as a cut-stump treatment. As a preventative measure, the use of privets as ornamentals should be discontinued, and existing plants should be gradually replaced by other native species, or at least non-invasive exotics.



EUROPEAN PRIVET Photo: [www.kulak.ac.be](http://www.kulak.ac.be)



COMMON PRIVET Photo: [environnement.ecoles.free.fr](http://environnement.ecoles.free.fr)

## SHRUBS BLACKBERRIES

Blackberries are scrambling shrubs that belong to the rose family Rosaceae. There are so many closely related species, subspecies and varieties that they are for convenience aggregated under the name *Rubus fruticosus*. Species from Europe and North America were introduced to South America as a food plant, the berries being popular for making jams and tarts. Many of these have become naturalised or have hybridised with one another and with indigenous species of *Rubus*.

Once introduced, they were spread by birds and mammals, which eat the berries and disperse the seeds in their faeces. Today, blackberries are invasive weeds in many countries of the world. In South America, they are particularly problematic in Chile, where some six million hectares are infested.

### Highly adaptable invader

Blackberries are highly adaptable plants, able to invade both natural and disturbed areas, including grasslands, riverbanks, forest edges, plantations, pastures and roadsides. They tend to form dense, prickly thickets that constitute a fire hazard during the dry season, and act as an impenetrable barrier. In plantations the thickets hamper forestry operations by restricting the movement of workers and equipment, while in agricultural areas they block access of livestock to grazing and watercourses. In natural areas they threaten biodiversity by reducing wildlife habitat and displacing indigenous vegetation.



## SHRUBS JAPANESE HONEYSUCKLE

The Japanese honeysuckle *Lonicera japonica* is a woody vine that is able to thrive in a wide variety of habitats. Introduced to South America for horticultural purposes, has been spread over long distances by birds and other animals that eat the fruits and disperse the seeds in their faeces. Today the species is invasive in parts of Brazil, Argentina and Uruguay, particularly in the Parana River basin.

The honeysuckle grows very rapidly, sending out runners that twine around vertical structures and form tangled thickets. It climbs up and over small trees and shrubs, outcompeting them for light and sometimes causing them to collapse under its weight. Few plants can survive in the deep shade beneath the blanketing canopy, so the invader ultimately alters forest structure by eliminating the understorey of herbs and shrubs and suppressing the regeneration of trees.

Once established the plant will resprout if cut or burnt, so the most effective form of control is to spray the foliage with a glyphosate herbicide.

## Endangering endemic hummingbird

Some impacts are less obvious. On Chile's Juan Fernandez islands, for example, the elm-leaf blackberry *Rubus ulmifolius*, also known as the elm bramble or zarzamore, is one of the greatest threats to the native flora and fauna. The islands – located more than 660 km off the coast of Chile – have a higher density of species and endemics than any other oceanic island. Indeed, the Juan Fernandez firecrown *Sephanoides fernandensis* is the only endemic hummingbird known from the world's islands, but its population is declining. One postulated reason is that it is being outcompeted by the more widely distributed green-backed firecrown *S. sephanoides*, which is better suited to feeding on the nectar of the invasive blackberry.

Blackberries are difficult to control as they will regrow if simply cut back. A glyphosate-based herbicide can be used as a cut-stump treatment or foliar spray after slashing. Some success has been achieved with the blackberry leaf rust fungus *Phragmidium violaceum*, which has been introduced to Chile and a number of other countries as a biocontrol agent.



ELM LEAF BLACKBERRY Photo: [www.tintazul.com.pt](http://www.tintazul.com.pt)



## Rambling Roses

A number of other members of the rose family are invasive in South America. For example, the sweetbriar *Rosa rubiginosa* was introduced from Europe in the early 1900s, and has spread throughout most of the Patagonian Andes region of Argentina and Chile. It prefers disturbed sites, and is common along roadsides in the vicinity of Buenos Aires. However, it also occurs in forest gaps and on the adjacent steppes, and has invaded a number of protected areas, including the world-famous Nahuel Huapi National Park.

Photo: [www.floridanature.org](http://www.floridanature.org)



Brooms are shrubs belonging to the legume family Fabaceae. The common name reflects the fact that their thin stems used to be cut and tied together to make brooms for sweeping floors. Native to various parts of Europe, brooms have been introduced around the world as landscape ornamentals and soil binders, often used for wasteland reclamation and sand dune stabilisation. Unfortunately, they have spread from these areas to invade disturbed sites such as logged or burned areas, eroded slopes, roadsides, riverbanks and agricultural land, as well as undisturbed grasslands, coastal scrub, open woodlands and forest edges.



## Control

The seeds are long-lived, and can remain dormant in the soil for many years until soil disturbance, fire or canopy removal stimulate their germination. The large seedbank complicates efforts to control broom, and necessitates ongoing monitoring and follow-up work. In addition, brooms are vigorous resprouters, so ineffective control can result in denser infestations.

A variety of methods are available for controlling brooms, and most success is achieved using a combination of these in an integrated approach. Young plants of up to about 1m tall can be removed by hand, although this is very labour-intensive. Hand-pulling is best done after rain – when the soil is loose – to ensure that the root system remains intact, as the plant will resprout from any pieces left behind. A weed wrench or claw mattock is effective in removing entire plants with stem diameters of up to about 6 cm, but efforts should be made to minimise soil disturbance so as to limit seed germination.

Brooms will resprout if clean cut with a saw, unless the stump is treated with an appropriate herbicide, such as glyphosate. Glyphosate can also be used as a foliar spray for dense seedlings and regrowth, while basal bark application of triclopyr in an oil carrier is an effective chemical control method for adult plants.

Fire is sometimes used to control brooms, but may stimulate germination from the seedbank. Very hot fires will kill the aboveground parts of the plant and prevent resprouting. They will probably kill some broom seeds too, but may also kill seeds of native plants, inhibiting rehabilitation. Similarly, goats will graze on broom and can be effective in reducing regrowth after initial control work, but they will eat native species as well.

The twig-mining moth *Leucoptera spartifoliella* and the seed weevil *Apion fuscirostre* were released for the biological control of Scotch broom in the United States, but they have limited impact and do not feed on French broom or Spanish broom. Research is underway to identify other suitable biocontrol agents.

## Aggressive invaders

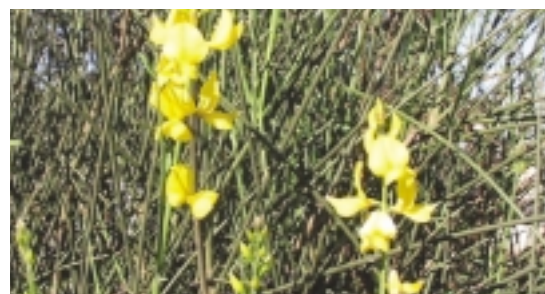
The most common broom in South America is the Spanish broom *Spartium junceum*, distributed throughout the continent. The Scotch broom *Cytisus scoparius* and the French broom *Genista monspessulana* are not as widespread, but where they occur they are more

aggressive as invaders. They tend to form dense, impenetrable thickets that displace native vegetation and constitute a fire hazard during the dry season. And since the foliage of brooms is mildly toxic and unpalatable to most wildlife and livestock, the thickets reduce forage and therefore the carrying capacity of the land for grazing animals. Most of the toxin – made up of quinolizidine alkaloids – is concentrated in the flowers and seeds, which can be harmful if ingested.

The success of brooms as invaders can be attributed to a number of factors. Like most other invasive species, they are able to thrive in the absence of the natural enemies that keep them in check in their native range. In common with other legumes, their mutualistic relationship with nitrogen-fixing bacteria gives them a competitive advantage in nutrient-poor soils. But it is their extremely efficient seed dispersal that accounts for their rapid spread. In late summer, the seed capsules burst open, scattering seed a few metres from the plant. From there they are carried to other areas in rivers and runoff, in gravel removed from riverbeds for construction work, in mud adhering to vehicles and machinery, and by ants, birds and other animals.



FRENCH BROOM Photo: bahiker.com



SPANISH BROOM Photo: Silvia R. Ziller

## SHRUBS GORSE

A close relative of the brooms, gorse *Ulex europaeus* is a prickly shrub that is native to western and central Europe. Starting from the turn of the 19th century, it was widely introduced as a hedge plant and for erosion control. Today it is considered invasive in temperate regions such as Australia, New Zealand and the east coast of the United States, and also in tropical mountainous areas, as in Sri Lanka, La Reunion and Hawaii. In South America, where the species is known as 'retamo', 'espinillo' or 'tojo', it is invasive in a number of countries, including Argentina, Brazil, Uruguay, Chile, Colombia, Ecuador and Peru.



many rural areas in the southern savannas.

Gorse produces massive quantities of seeds, which are ejected from the pods and land a few metres from the adult plant. The seeds are typically spread in water and in mud clinging to vehicles, people and animals, but birds and ants also play a role in dispersal in some areas. The seeds can remain dormant in the soil for at least 50 years, and fire or other soil disturbance

may stimulate them to germinate *en masse*.

This feature may be exploited in the control of gorse – thickets are often burned so that the regrowth and new seedlings can be sprayed with herbicides, although this technique will also impact native plants. The cut-stump treatment is an effective method of control but very labour-intensive, so large infestations are sometimes cleared mechanically with bulldozers or tractors equipped with rippers. Re-establishment of gorse may be inhibited by planting suitable non-invasive replacement species or allowing goats to graze on gorse regrowth. In Chile, some success is being achieved with biological control using the herbivorous insect *Agonopterix ulicetella*, although other biocontrol agents are needed to complement its effectiveness. The best results are achieved with an integrated approach, using a number of methods in combination. Whichever methods are used, however, ongoing follow-up work is vital.

### Prickly pest

Gorse is a very adaptable species and easily becomes established on disturbed sites, such as roadsides, farmlands and riverbanks, but also invades natural areas. It is considered a pest in agriculture and forestry, because it forms dense thickets that reduce grazing land and act as an impenetrable barrier to the movement of people and animals. It increases the risk of fire too, because it is highly flammable.

Gorse is also a threat to biodiversity, as it displaces native species. In Colombia, for example, gorse is invading the montane vegetation of the Andes, reaching altitudes of 3 500 m, while in Argentina it is advancing in natural environments in the pampas and Patagonia. In Brazil, it has been reported as problematic in two national parks and



GORSE Photo: Silvia R. Ziller

## GRASSES



Brachiaria. Photo: Silvia R. Ziller

A number of grass species from Africa have deliberately been introduced to other parts of the world to provide grazing pasture for livestock, or to rehabilitate rangeland degraded by drought or overgrazing. In South America, approximately 53 million hectares of humid tropical forest in the Brazilian Amazon Basin alone have been converted to pasture, as has some 40 million hectares of native tropical savanna in Colombia, Venezuela and Brazil.

Apart from the dramatic loss of native vegetation resulting directly from the conversion of forest and savanna to pastures dominated by African grasses, in many instances the exotic grasses have spread to invade natural areas, where they represent a significant threat to biodiversity and cause changes in ecosystem processes.

Even before they were used to establish pastures, however, African grasses were inadvertently introduced to the Americas, when their small seeds escaped detection in other imported goods. For example, it is thought that Guinea grass and Pará grass may have been introduced to the West Indies and Brazil on slave ships, as far back as 1684.



PARÁ GRASS Photo: <http://evergreen.asn.au>

**Pará grass** *Brachiaria mutica* is now one of the most widespread species in Brazil, where it is known as 'capim angola'. Although it cannot tolerate heavy grazing pressure, it will persist in flooded areas. It has also commonly been used to stabilise and revegetate slopes alongside highways. This has facilitated its dispersal, as the seeds can be transported by passing vehicles over long distances. In accordance with its affinity for water, Pará grass is particularly adept at invading watercourses.

Several other species of *Brachiaria* were more recently introduced to South America for pasture establishment. Indeed, they comprise some 85% of the area planted with exotic grasses to form pastures in the Cerrado, the savanna





GUINEA GRASS Photo: [www.hear.org](http://www.hear.org)



KIKUYU Photo: <http://tncweeds.ucdavis.edu>

region of Brazil's central plateau. However, they have begun escaping from pastures to invade natural systems, where they tend to exclude and replace native grass species that are superior in terms of forage quality. As a result, their invasion may result in loss of agricultural productivity, as well as biodiversity.

**Guinea grass** *Panicum maximum* is another species that is common along roadsides, as well as on other disturbed land. It is capable of forming dense infestations, which constitute a fire hazard. And since it is better able to tolerate fire than native species, it comes to dominate areas that have been burnt. It has been less successful in invading pastures, however, as it cannot withstand constant grazing pressure.

**Buffelgrass** *Pennisetum ciliare* is the most popular of the African grasses planted to enhance livestock production in the dry tropics and subtropics of the Americas. Where buffelgrass has escaped from pastures and invaded the surrounding areas, it fuels fires that indigenous plants are not adapted to withstand.

**Kikuyu** *Pennisetum clandestinum* has been widely planted in more humid parts of the world, both for pastures and lawns. Its fast growth rate is considered a boon for grazing, but it displaces a variety of beneficial species, including nitrogen-fixing legumes that maintain nutrient levels in the soil. This necessitates heavier application of fertiliser, which is not only costly but has secondary environmental impacts, such as nutrient enrichment of watercourses and subsequent algal blooms and waterweed infestations. It is also considered a water-thirsty and high-maintenance lawn plant in some regions. Kikuyu is listed as a noxious weed in many countries, as it rapidly encroaches into natural areas and excludes indigenous vegetation. In Colombia it has successfully invaded cold, high-altitude areas.

The **lovegrass** *Eragrostis plana* was introduced to Argentina during the 1940s and later to Brazil, where it is known as 'capimannoni' after the rancher who introduced it during the 1960s, Ernesto Annoni. Like other lovegrasses it is allelopathic, able to inhibit the germination and growth of neighbouring plants by releasing chemical substances into the soil. This allowed it to form dense monocultures as



BUFFELGRASS Photo: [www.tarleton.edu](http://www.tarleton.edu)



WEeping LOVEGRASS Photo: [www.tarleton.edu](http://www.tarleton.edu)



THATCHING GRASS Photo: www.hear.org



BERMUDA GRASS Photo: www.hear.org

it rapidly invaded pastures and natural areas. It not only destroyed biodiversity, but also reduced the amount of forage available, as the grass is too fibrous to be palatable to cattle. In 1978 the Brazilian government banned the sale of lovegrass seed, but by that time the grass had already spread 20 000 hectares in the southern parts of the country. Its seeds were dispersed over long distances by vehicular traffic on roads. In 1997 it covered 500 000 hectares throughout Brazil's southern states and in neighbouring Argentina and Uruguay. Together with a related species, the weeping lovegrass *Eragrostis curvula*, it has now invaded an estimated 2 million hectares, mainly comprising open areas degraded by farming, forestry or fire.

The **thatching grass** *Hyparrhenia rufa*, known in South America as jaraguá, easily establishes in tropical areas, and aggressively invades natural areas. It outcompetes and smothers other weeds, and – since it is a fire-adapted species – it readily replaces native plants after fires.

**Molasses grass** *Melinis minutiflora* is planted as pasture but also used to revegetate highway slopes in tropical areas of South America. It has invaded roadsides, agricultural land, forestry plantations, as well as natural vegetation,

where it displaces native species. By increasing the fuel load, it promotes hotter than normal fires, which kill the seeds of indigenous species in the soil.

**Bermuda grass** *Cynodon dactylon* has been introduced throughout much of the warm-temperate and subtropical world, primarily for use as a lawn and as a forage grass. In Brazil it is now widely distributed on sandy or saline soils of open sites, including roadsides, agricultural fields, orchards, irrigation canals and wastelands.

MOLASSES GRASS Photo: www.hear.org



MOLASSES GRASS Photo by Carlos Romero Martins

## RODENTS RATS

Rats are the world's most widespread invasive alien mammals, with the greatest economic impact. The costs associated with the approximately 250 million rats in the United States, for example, have been estimated at \$19 billion per year. However, rats also cause significant environmental impacts, and have contributed to the extinction of many species of wildlife.

### Black versus brown

The two most common invasive alien rats worldwide are the black rat *Rattus rattus* and the brown rat *Rattus norvegicus*. The black rat is the more widely distributed of the two. Thought to be indigenous to the Indian subcontinent, it spread around the world on sailing ships, and for this reason it is also known as the ship's rat.

The brown rat, also called the Norwegian rat, is the larger rat. It is believed to have originated in northern China but had spread to Europe by the early 1700s, after which it was probably transported on ships to the rest of the world. It is a good swimmer and thrives in sewers, as well as buildings, where it tends to inhabit basements and cellars. In contrast, the black rat prefers the upper stories and ceilings of buildings, and is therefore known as the roof rat in many regions.

### Indiscriminate feeders

Rats cause a variety of socio-economic impacts by eating crops and stored grain, contaminating food stocks with their waste, and chewing through power cables. Living in such close association with people, they play a major role in spreading diseases, including leptospirosis and hantavirus pulmonary syndrome.

They also have a destructive effect on biodiversity. Both species are omnivorous and eat a wide range of foodstuffs, including seeds and seedlings, fruits and berries, eggs and small animals. By preying on other species or competing with them for food, they have caused the decline of many small mammals, birds, reptiles and invertebrates. Their effect has been particularly severe on islands – they are responsible for more island extinctions of birds, snakes and lizards than any other predators. On the Galapagos Islands, for example, they have had a detrimental impact on dark-rumped petrels and Floreana mockingbirds.

Most successful control programmes have made use of poisoned bait, usually containing brodifacoum as the active ingredient. In the past, cats were sometimes released on islands to control rat populations, with devastating consequences for birds and other small animals.



### Rats and 'Black Death'

Rat-borne diseases have claimed more human lives than all the wars in history combined! As a reservoir for the bubonic plague bacterium *Yersinia pestis*, the black rat is held accountable for approximately 200 million deaths in medieval times alone.

Bubonic plague is transmitted by fleas from rats to people, but then spreads rapidly as it is highly infectious. An outbreak occurred in China in the early 1330s, but the disease was not introduced to Europe until 1374, when several Italian merchant vessels returned from a trip to the Black Sea – a key trade link with China. Many of those onboard were already dying when the ships docked in Sicily, and the disease quickly spread throughout the surrounding countryside. The following year it reached England, where it was known as the Black Death because its symptoms included black spots on the skin. The disease ultimately killed almost a third of Europe's people.

Outbreaks of bubonic plague continue to occur – mostly in rural areas – with the World Health Organisation reporting 1 000 to 3 000 cases globally every year. During the last decade, Peru has had the highest incidence of bubonic plague in South America. Fortunately, the disease can now be treated with antibiotics.



Photo: <http://wifcb.ucdavis.edu>

A beaver dam on the island of Tierra del Fuego. Photo: [www.answers.com](http://www.answers.com)



The American beaver *Castor canadensis* is North America's largest rodent. Its native range includes most of the forested regions of Canada and the United States, although its numbers were decimated in some areas through hunting for its commercially valuable fur. In order to share in this lucrative trade, in 1946 Argentina imported 25 beaver pairs from Canada to Tierra del Fuego. Finding themselves in a land with abundant forests and streams, a climate similar to their native lands, and no natural predators, the beavers thrived.

### **Fur versus floods**

The introduced beavers were released on Argentina's side of Lake Fagnano, and by 1964 they had spread throughout the lake's tributaries as well as to the Chilean side. Shortly before this, however, they had already invaded Chilean territory by swimming 7 km across the Beagle Channel to colonise Navarino Island. By the early 1990s, beavers numbered some 20 000 on Navarino Island and 41 000 in Chilean Tierra del Fuego, where densities averaged approximately 6 colonies per km<sup>2</sup>. In Argentine Tierra del Fuego, where hunting levels were higher, about 25 000 beavers occupied 90% of all streams.

By this time, it had already been realised that the benefits of introducing beavers as a fur resource were outweighed by their negative impact on local streams and



BEAVER Photo: <http://dmr.state.il.us>

forests. Beavers fell trees to dam streams, creating a deep pool around their lodge that provides protection from terrestrial predators as well as an underwater food store. Typically the dams cause flooding, which damages the indigenous *Nothofagus* beech forests by drowning trees in low-lying areas and altering nutrient dynamics. Forest regeneration is also inhibited, as beavers kill young saplings by nibbling at their bark and shoots. Furthermore, by slowing the flow of fast streams, the dams change riverine habitat and may increase siltation.

Programmes are already in place to control beaver populations on Tierra del Fuego and surrounding islands in the Beagle Channel. However, there are concerns that beavers may recently have crossed the Straits of Magellan and reached the mainland, where they would be much harder to control. And with an abundance of suitable streams and forests to colonise, beavers could wreak havoc on Patagonia's fragile ecosystems.

## Mink

The mink *Mustela vison* – also known as the vison – is widely distributed across North America. It was first introduced to South America during the 1930s, when it was imported into both Chile and Argentina for commercial fur production. In both cases, the first attempts at fur-farming failed. However, by 1960 more than 50 mink farms were operational in Argentina. These supplied stock for renewed efforts at mink-farming in Chile, but when economic returns failed to meet expectations, many of the animals were simply set free. Some animals also escaped from Argentine farms, dispersed through inter-connecting waterbodies, and used low mountain



MINK Photo: [www.biopix.dk](http://www.biopix.dk)

passes to cross over the Andes range into Chile. Today the mink is widely distributed throughout Patagonia, and has recently reached Tierra del Fuego and Navarino Island.

The mink is an opportunistic predator that can exploit a wide range of foods, so it is considered a pest in most of the world's invaded regions. In Argentina it often kills domestic poultry and has even been known to attack newborn lambs. It has been linked to a decline in numbers of water-fowl and mammals, including the indigenous coypu *Myocastor coypus*. It also preys on fish, raising concerns about its impact on recreational fisheries for introduced salmonids.

## Muskrat

Like the beaver, the muskrat *Ondatra zibethicus* was introduced from Canada to Tierra del Fuego as a fur resource. In 1948, 75 males and 150 females were released on the Argentine side of Tierra del Fuego Island, and they multiplied so rapidly that in 1954 they were declared vermin. They soon invaded the Chilean side of Tierra del Fuego, as well as Navarino Island. Fortunately, they do not appear



MUSKRAT Photo: [www.astronomy-images.com](http://www.astronomy-images.com)

to have reached the mainland.

Muskrat feed primarily on aquatic plants, but they also consume crustaceans and molluscs. Although little is known about their effects on native fauna, they are considered harmful to the local flora. This is because their tunnelling activities damage earthen dams and irrigation ditches, and the resulting flooding causes loss of habitat.



BEAVER Photo: <http://www.fcps.k12.va.us>



The European rabbit *Oryctolagus cuniculus* is the ancestor of all domestic varieties of rabbit. Indigenous to Spain and Portugal, it was introduced throughout Europe in the Middle Ages. Later, it was taken to other continents by colonialists, hoping to replicate the environment of their homelands. Rabbits were also carried aboard sailing ships as a fresh meat supply, and often released on islands as a source of food for passing or shipwrecked mariners. In South America, the European rabbit is an invasive pest in Chile and Argentina.

### A plague of rabbits

The European rabbit was introduced to mainland South America in 1884, when a group was released on an island in the Cauquenes Lagoon, in central Chile. When the water level receded during an extended drought, the rabbits escaped from the island and began spreading to the north and south. By 1950 they had crossed over the Andes into Argentina, where they continued to expand their distribution, occupying some 50 000 km<sup>2</sup> by the mid 1980s.

Prior to the rabbit's introduction in central Chile, however, in 1880 it had been released on Argentina's side of Tierra del Fuego Island, as well as a number of other islands in the Beagle Channel. Then, in 1936, two pairs were set free on the Chilean side of Tierra del Fuego. This triggered a population explosion that peaked in the early 1950s, when densities averaged 30 rabbits per hectare and over a million hectares had been invaded. Rabbits somehow also crossed the Straits of Magellan to the mainland, and expanded their distribution to the north.

As with most invasive species, the rabbit was able to proliferate so successfully because its natural enemies were absent. In its native range, the rabbit is preyed upon by predators such as eagles and foxes, and also heavily hunted by people for food. Predators in Chile and Argentina, accustomed to pursuing prey that ran in a straight line for the nearest shelter, were initially bewildered by the rabbit's escape behaviour, which includes

rapid zigzagging, dodging, leaping and back-tracking. Most of the invaded area was also sparsely inhabited by people, and rabbit meat was an unfamiliar food, so hunting pressure was low.

In response to the reduced threat, rabbits were able to venture out from the shelter of scrubby vegetation, which they typically inhabit in their native range, to feed on the abundant grass of their new home. With an unlimited food supply, they were able to raise more young and disperse to new areas.

Indigenous predators eventually adapted their hunting behaviour, and acquired skills enabling them to catch the new prey species. Today, the rabbit is an important part of the diet of many predators, particularly the culpeo fox *Pseudalopex culpaeus* and black-chested eagle *Geranoaetus melanoleucus* in central Chile, and the Magellanic owl *Bubo magellanicus* in Argentine Patagonia. People also recognised the commercial value of the invader and began hunting rabbits, primarily for export of the meat, pelt and skins to Europe.

Nevertheless, rabbits are still reviled because of the damage they cause to agricultural areas and the natural environment. They eat a variety of vegetable and grain crops, and compete with livestock for forage, thereby reducing the carrying capacity of grazing land. In pine plantations they consume new shoots, so foresters must implement rabbit control programmes before planting young trees. They alter natural plant communities through their heavy consumption of perennial herbs, shrubs and seedlings, threatening the habitat of other animals while also competing with them for food. Their overgrazing and burrowing results in increased soil erosion, which may in turn cause siltation of river systems. All of these impacts place indigenous species at risk. Indeed, in Australia rabbits have been held responsible for a number of extinctions.

### Control

A variety of methods have been attempted for controlling invasive rabbits, with varying success. The most notorious example is biological control using the myxoma virus, which causes the disease myxomatosis. The virus was first released in Australia in 1950, and because it initially devastated rabbit populations, it was introduced to Tierra del Fuego in 1953. However, rabbits soon develop resistance to the disease, and within a few generations have become immune. Fortunately, immunity weakens over time in the absence of the virus so new outbreaks periodically occur, helping to limit the population size.

During the 1990s, a second virus was introduced as a biological control agent into Australia, and then into New Zealand illegally. The calicivirus causes rabbit haemorrhagic disease (RHD), which has resulted in mass mortalities in some

areas, but has proved less effective in cooler, wetter areas.

Predators have sometimes been introduced as a crude method of biological control, often with disastrous consequences, as rabbits were overlooked in favour of species that the predators found easier to capture. Likewise, poisoning programmes may kill non-target animals if they are not conducted with care. These make use of baits such as oats, carrots or bran pellets impregnated with the

poison 1080 (sodium monofluoroacetate) or the anticoagulants pindone or brodifacoum. Fumigation of warrens is also effective, while destruction of warrens and surrounding refuges, shooting and trapping can all be used for ongoing maintenance control once populations have been significantly reduced by other methods. Most success is achieved using an integrated approach, combining a number of different methods.



Photo: www.ittofauna.org

## European Hare

Native to Europe and parts of Asia, the European hare *Lepus europaeus* was first introduced to South America in 1888, when three dozen hares were imported from Germany and released on a private ranch in Argentina. In 1896 it was also introduced from Germany to Chile, and today it has spread throughout both countries, except for their territories on Tierra del Fuego Island. By 1983 it had invaded Uruguay, Paraguay and the southern parts of Bolivia and Brazil, and in the latter half of the 1990s it reached Peru.

Despite the fact that the European hare is a lucrative wildlife commodity – more than 6 million hares are shot each year in Argentina alone and the meat, pelts and skins exported to Europe – it is considered a serious pest in both Argentina and Chile. The hare is a generalist herbivore, foraging primarily at night on a variety of green plants during summer, and resorting to twigs, buds, saplings and the bark of shrubs and young trees in winter. As a result, it causes extensive damage to grasslands, crops, orchards and forestry plantations, and competes with domestic livestock for pastures.

It has also been accused of displacing indigenous herbivores, such as the tapeti, Patagonian cavy and Chacoan mara, through competition for food. However, its presence appears to have been beneficial to other animals in some respects. It increases the prey supply to predators – forming an important part of the diet of puma, fox, ferret and some raptors – and thus reduces predation pressure on livestock and indigenous wildlife.

## RODENTS SMALL INDIAN MONGOOSE

The native range of the small Indian, or Javan, mongoose *Herpestes javanicus* – also known as *H. auropunctatus* – extends from Pakistan to the south coast of China, and throughout the Malaysian Peninsula and Java. Starting in the 1870s, it was widely introduced to the West Indies and adjacent South American mainland, as well as Mauritius, Hawaii and several other islands, to control rats and snakes in sugarcane fields or other crops. It was only partly successful in this regard, but it spread rapidly and soon became a pest.

Apart from killing domestic poultry, the mongoose began preying on indigenous animals. Ground-nesting birds



and their eggs were particularly easy targets, but small mammals and reptiles especially snakes and lizards – were also threatened. The mongoose has already been held responsible for the extinction of two birds in Jamaica and seven amphibian and reptile species in Puerto Rico. In the US Virgin Islands, Barbados and Gaudelope, it is one of the main predators of hatchlings of leatherback, green and hawksbill turtles. Furthermore, the species is a vector and reservoir of rabies and leptospirosis.

In South America, the mongoose is well established in Suriname, Guyana and French Guiana, but it also occurs throughout the offshore island states.

The red deer *Cervus elaphus*, native to Eurasia, was introduced to Argentina about a century ago. As the population grew in size and distribution, it spread into Chile, although some local introductions were also made there. Today the red deer occupies an area of some 50 000 km<sup>2</sup> on both sides of the Andes, where it occurs in all available habitat types – from dense rainforests to dry, treeless steppe. It has invaded a number of national parks, and has reached high densities in several locations.

### Unwanted ungulate

Although it is valued by hunters as a trophy species, the red deer is generally considered a pest by conservationists because of its negative impact on natural ecosystems. Its

selective grazing and browsing on favourite plant species may alter the structure and composition of plant communities, or even inhibit forest regeneration at high densities. Overgrazing of groundcover, as well as trampling, may increase soil erosion and destroy habitat required by other species. For example, the previously abundant rodent *Euneomys petersoni*, which evidently preferred living in thick, moist grass, all but disappeared once this habitat was virtually eliminated by the red deer's overgrazing.

The red deer may also compete for food with native ungulates such as the guanaco *Lama guanicoe*, Patagonian huemul *Hippocamelus bisulcus* and pudu *Pudu pudu*, as well as livestock. It poses an additional threat to livestock in that it may facilitate the spread of bovine tuberculosis and other diseases, due to its ability to disperse over long distances.





## MAMMALS FERAL PIGS AND WILD BOAR

Feral pigs are descendants of wild boar *Sus scrofa*, originally native to Eurasia and North Africa. They were taken to other parts of the world by early migrants, who either released them for hunting when food was required or kept them as domesticated animals. Later their dispersal was continued by European explorers, sealers, whalers, immigrant settlers and colonialists. Domestic pigs were typically allowed to range freely, which inevitably led to the establishment of feral populations.

The descendants of these pigs are now found in most Central and South American countries. In many areas they have interbred with wild boar, introduced more recently by game hunters and meat producers. The boar were either deliberately released as founder stocks to form naturalised populations, or escaped from captivity. For example, in about 1906 the owner of a ranch imported wild boar from Europe to Argentina. The boar soon spread, and within twenty years they had crossed the Andes mountains into Chile. Today wild boar are found in a large area of the temperate forest zone of both countries.

Wild boar and their feral cousins are generally harmful to vegetation, as they consume large quantities of fruits, seeds, seedlings, roots and bulbs. They also eat invertebrates such as earthworms and snails, and probably other small native fauna. They not only reduce the food available for other animals, but impede plant regeneration by



uprooting seedlings and disturbing the soil with their rooting behaviour. Furthermore, they disperse the seeds of alien plants in their faeces. They are considered an agricultural pest, as they damage crops through their feeding and trampling, and have been known to prey on young lambs, goats and calves. They also spread diseases, such as leptospirosis and foot-and-mouth disease.

Feral pigs have had a major impact on islands, particularly by preying on the eggs and chicks of ground-nesting birds. Fortunately, great successes have recently been achieved in eradicating pigs from some islands, including those of Ecuador's Galapagos archipelago (see p. 42).



Photo: [www.wildpark-rolandseck.de](http://www.wildpark-rolandseck.de)

# FERAL ANIMALS IN GALAPAGOS

**The world's biggest restoration effort is currently taking place in the Galapagos islands of Ecuador. The specially adapted plants and animals that so influenced Charles Darwin in developing his theories of evolution have been threatened by a variety of invasive alien species for over a century. Now these unwelcome guests have been given their eviction orders, so that the islands can be returned to their former glory.**

## Goats

The goat *Capra hircus* is considered the single most destructive herbivore introduced to the world's islands. The species originated in Asia, but was domesticated and distributed around the globe, often being released on islands to provide a ready supply of meat and milk. Feral populations can cause massive ecological degradation. Their overgrazing and trampling tend to increase erosion and habitat destruction, reducing the plant cover needed by other animals to shelter from predators or the elements. They also impact indigenous communities by outcompeting other herbivores.

Starting in the early 1970s, ground-hunting over three decades successfully eradicated goats from the Galapagos islands of Española, Marchena, Rábida and Santa Fe, and natural re-vegetation of the islands has restored some of the original habitats. On Pinta, more than 41 000 goats were removed between 1971 and 1982. The campaign was revived in 1999, and by 2003 the last goats had been eliminated. This was the world's largest removal of an island goat population using ground-based methods.

A critical factor in the successful removal of goats at low density levels on Pinta was the use of so-called 'Judas' goats. A number of goats fitted with radio-collars and released will soon associate with the few remaining goats, betraying their location to hunters.

The hunting techniques used during the Pinta eradication campaign were perfected and further developed when implemented on Santiago Island in December 2001. Starting in 2004, helicopters were used to transfer highly

trained hunters and tracking dogs to remote areas of the island. Within three weeks, goat densities had been lowered significantly. By June 2004, 90% of the goats and all the feral donkeys had been eliminated, and it is expected that the island will be declared goat-free by the end of 2005. A dramatic recovery of native vegetation in the highland areas of the island is already evident.

Now the focus has shifted to Isabela, the largest island in the archipelago and that which contains the highest concentration of endemic species. Many of these species – including five species of giant tortoise – are threatened by the presence of a massive goat population. The island is divided into two parts by a rugged lava field that acts as a barrier to the movement of animals, and in the mid 1990s northern Isabela alone was home to as many as 100 000 goats. In 2004, aerial hunting from helicopters began in northern Isabela. Once densities had been reduced, hunters and their dogs took over. By the beginning of 2005, two-thirds of northern Isabela was already at 'Judas goat level', and it is expected that the last remaining goats will have been eradicated within a year.

## Pigs

Feral pigs are thought to have played a major role in the extinction of a number of species on the Galapagos islands. Of particular concern is their predation on the eggs of ground-nesting birds, sea turtles and giant tortoises – indeed, a single pair of pigs managed to destroy 23 tortoise nests on Santa Cruz island over a one-month period during the 1970s!

Pigs were probably introduced to Santiago island shortly after Darwin's visit, and by 1875 they were already abundant there. Control work began on Santiago in 1968, with sporadic hunting, trapping and poisoning with 1080 (sodium monofluoroacetate). In 1995 hunting effort was intensified, together with increased use of hunting dogs and poisoning, now employing goat carcasses as bait.

In 1998 the pig eradication programme was reorganised and adapted to incorporate new methods, such as GPS and GIS technologies, and using 1080 in combi-



Photo: www.dlwc.nsw.gov.au



Photo: www.meyers-naturfoto.de

nation with an anti-emetic. The latter was to delay the effects of nausea and vomiting brought on by the poison, and thus increase the likelihood of pigs ingesting a lethal dose. The pigs nevertheless became bait-shy – possibly because they could smell the anti-emetic – so from December 1999 warfarin was used in place of 1080. Warfarin is a poison commonly used to kill rats, and it has a number of advantages over 1080. Most importantly, it is slow-acting, so symptoms appear well after a lethal dose has been ingested, reducing the chance of pigs associating bait with feeling ill. Furthermore, warfarin is less toxic to humans, dogs and other non-target species, and an antidote is available. Ultimately, the only non-target species known to have been killed by the poisoning programme was the black rat – also an invasive species on the island.

The last pig to be shot on the island was in April 2000, after which no further pigs could be found by hunters. In July an intensive monitoring programme was initiated to determine whether any pigs remained, using poison-free goat carcasses equidistantly distributed around the island. When one of these carcasses showed evidence of pig-feeding in October, a toxic replacement was laid, and two weeks later a dead pig was found in the vicinity. Despite ongoing monitoring, no further pigs were detected during the following 18 months, and in May 2002, Santiago Island was declared pig-free for the first time in at least 127 years. Almost 19 000 pigs were removed during the 30-year campaign, and Santiago is now the largest island from which an established pig population has been eradicated worldwide.

## Cats

Feral cats *Felis catus* have a devastating effect on island biodiversity. In the past cats were often introduced to islands to control rat infestations, but instead targeted other small mammals, reptiles and birds. With growing awareness of their impact, feral cats have now been removed from more than 40 islands worldwide.

In 2001, a cat eradication project was initiated in Baltra, a small island in Galapagos controlled by the



Photo: www.forestryimages.org

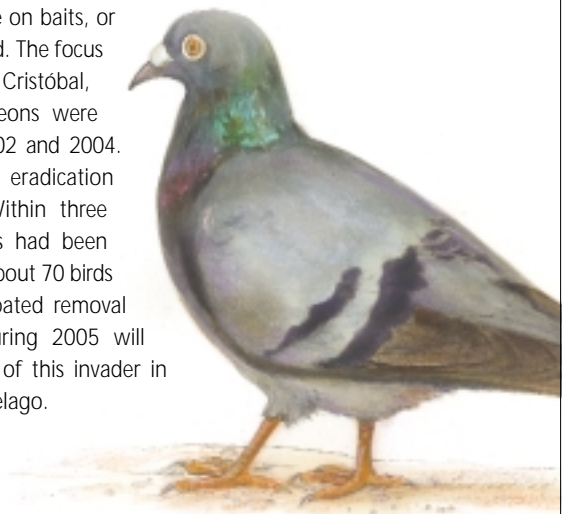
Ecuadorian Air Force. Great success was achieved using a combination of traps, poisoning (1080 in fish bait), and hunting at night with rifles and spotlights. By the end of 2003, cats appeared to have been eradicated, or at least reduced to very low numbers. The project paved the way for the re-introduction of land iguanas – driven to extinction on the island when it was used as a military base in World War II – to be intensified.

Feral cats are now being controlled on Santa Cruz, while other islands are being monitored to identify areas where cats are threatening native species.

## Pigeons

The pigeon or rock dove *Columba livia* was introduced to the Galapagos archipelago in the early 1970s, and by the mid 1980s had become established on three islands – Santa Cruz, San Cristóbal and Isabela. By 2000, populations had increased significantly, raising concerns about their potential to transmit avian diseases to indigenous birds, including the endemic Galapagos dove.

In 2001, a pigeon eradication programme was initiated on Santa Cruz. Over an 18-month period, 429 birds were removed by shooting, stupefying using alpha-chloralose on baits, or catching them by hand. The focus then shifted to San Cristóbal, where 802 rock pigeons were removed between 2002 and 2004. In September 2004 eradication began on Isabela. Within three months, 347 pigeons had been eliminated, and only about 70 birds remained. The anticipated removal of these pigeons during 2005 will mark the eradication of this invader in the Galapagos archipelago.



## OTHER INVASIVE SPECIES

Efforts are also being made to eradicate other animals, especially the black rat *Rattus rattus* (see page 35). Insects such as the little fire ant *Wasmannia auropunctata* (page 51) and the cottony cushion scale *Icerya purchasi* (page 69) have been successfully controlled. Invasive plant species are being removed from Galapagos too – for example, the three blackberry species *Rubus adenotrichus*, *R. megalococcus* and *R. ulmifolius* have already been eradicated, and nine other plant invaders are now being targeted.

## BIRDS HOUSE SPARROW

The house sparrow *Passer domesticus* is indigenous to Eurasia and North Africa, but is now widely distributed in other parts of the world. Its initial introduction to South America was probably to Buenos Aires, Argentina, in 1872, and it is now well established on the continent. However, its distribution is limited to areas settled by humans, as it is largely dependent on people for food. As its name suggests, it is common around houses, where it can forage for scraps of food discarded by humans. There are many reports of it feeding in canteens in buildings, even learning to activate automatic doors to gain entry. It is often found in stables, barns and granaries, where it can eat seeds and grains, sometimes stolen from animal feed or pecked from droppings. It also feeds on a variety of insects, spiders, berries and flowerbuds. Indeed, it is the bird's generalist diet that has allowed it to become established throughout its introduced range.

Unfortunately, the house sparrow's success as an invader has been at the expense of indigenous birds in regions where it has been introduced. It nests in buildings but also in natural cavities in dead wood, construction poles and fence posts, and it is accused of causing the decline of a number of cavity-nesting species. The house sparrow outcompetes such birds for nest sites and aggressively evicts those that attempt to nest in its territory. In doing so the males may destroy the eggs of a nesting pair, kill nestlings and sometimes even kill incubating females.



### DID YOU KNOW?

The house sparrow has been implicated as the main reservoir for mosquito-borne West Nile virus in the United States. The virus is widely distributed in Africa, Asia and Europe, but had never been recorded in the western hemisphere prior to August 1999, when there was an outbreak in New York.



Photo: [www.ixobrychus-drustvo.si](http://www.ixobrychus-drustvo.si)

## The world's worst urban bird pest

The number one urban bird pest is the feral pigeon *Columba livia*, descended from the domesticated European rock dove. Found throughout the world, it is widely distributed in South America, but concentrated in cities and towns, where it causes considerable damage to buildings and monuments because of its corrosive droppings. It also poses a health hazard, since it is capable of transmitting a variety of diseases to humans – including ornithosis and histoplasmosis – as well as to domestic poultry and wildlife. It mainly feeds on grain, seeds and insects, but will also scavenge discarded human food. Worldwide, little effort is made to control pigeon populations in urban areas, the focus instead being to manage the problems they cause. For example, buildings are often 'pigeon-proofed' with metal spikes or regularly spaced nylon line, which will prevent the birds from landing.

## BIRDS EUROPEAN STARLING

The European, or common, starling *Sturnus vulgaris* is native to Eurasia, and migrates into north Africa to over-winter. It was intentionally introduced to North America, Australia, New Zealand and South Africa, mainly for aesthetic reasons but sometimes also to control insect pests – ironically, it is now considered a pest itself. More recently it has been introduced to South America, and there are fears that it will spread through much of the continent unless urgent action is taken.

### Small beginnings

The starling is currently only found in a small part of Argentina, where it is known as the *estornino pinto*. It is thought to have been introduced to Buenos Aires in about 1987, and has now become established in the surrounding coastal zone, between Tigre and La Plata. The immediate priority is to prevent it spreading up the Rio de La Plata to the Parana Delta and neighbouring Entre Rios province, renowned for their rich biodiversity and high productivity. It is vital to take advantage of the opportunity to eradicate this invader from South America while it is in an early stage of its colonisation, and restricted to a limited area.

The North American experience illustrates how quickly this invader can spread from a relatively small founder group introduced at a single point. The starling was first introduced to the United States in 1890, when 100 starlings were released in New York's Central Park, apparently in the hope that all birds mentioned in Shakespeare's works would become established in the New World. Today the starling is widely distributed across the United States and Canada, with a population estimated at about 200 million birds.

The species' success as an invader can be attributed to the fact that it is a habitat generalist, able to exploit a wide variety of habitat types, nest sites and food sources. Its ability to co-exist with humans allows it to become established in agricultural fields, cities, sewage treatment facilities and garbage dumps.

### Health hazard and agricultural pest

European starlings are highly colonial, gathering in flocks that may number in the thousands to feed, roost and migrate, although they tend to be solitary nesters. Their droppings cause sanitation problems in and around buildings, are corrosive to paint and plaster, and provide a growth medium

for the fungus that causes the human respiratory disease histoplasmosis. The birds themselves carry diseases that may be transmitted to humans, and itch-causing mites in their feathers. Furthermore, large flocks of starlings close to airports pose a bird strike hazard to planes.

European starlings also cause economic losses in agriculture. They are a potential threat to domestic animals, as they can transmit diseases by contaminating food and water sources at livestock and poultry facilities with their droppings.

They sometimes impact crop production by eating cultivated fruits, particularly berries and grapes, and by uprooting sprouting plants and eating sowed seed in grain fields.

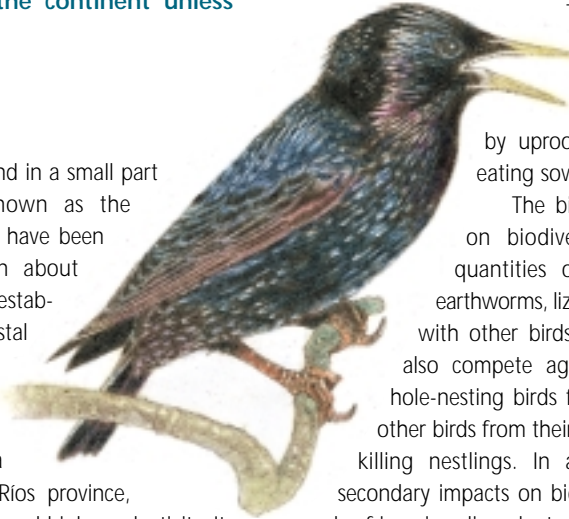
The birds have a negative affect on biodiversity, as they eat large quantities of insects, spiders, snails, earthworms, lizards and frogs, and compete with other birds for these resources. They also compete aggressively with indigenous hole-nesting birds for nest sites, often driving other birds from their nests, destroying eggs and killing nestlings. In addition, the birds cause secondary impacts on biodiversity by dispersing the seeds of invasive alien plants.

### Control

In most invaded countries, there is no systematic attempt to control European starlings, and effort is focussed instead on mitigating their impact. For example, birds can be excluded from buildings by sealing up holes or covering them with strong netting, while commercially available repellents, coiled razor wire or spiked boards can be used to discourage roosting on ledges or roof beams.

Strips of plastic or rubber hung in open doorways of farm buildings have been successful in keeping birds out, while allowing access to people, machinery and livestock. A variety of farm management practices may also be employed to limit food and water available to starlings, and hence make the livestock environment less attractive to them. Where cost-effective, netting can be used to protect fruit crops such as grapes and berries.

Frightening is effective in dispersing starlings from roosts, small-scale fruit crops, and some other troublesome situations, including airports. However, poisoning with Starlicide is the only effective way to kill starlings. Poisoned birds experience a slow, non-violent death, usually dying 24 to 36 hours after feeding, often at their roost. Pre-baiting (using a non-poisonous bait) should be conducted for a few days prior to poisoning, to accustom the birds to feeding on bait at a particular location.



## BIRDS MONK PARAKEET



The monk parakeet *Myopsitta monachus* – also known as the Argentine cotorra – is indigenous to Argentina, Uruguay, Paraguay, Bolivia and southern Brazil. It was widely introduced to other continents through the pet trade, and established breeding populations in some areas after escaping from captivity or being deliberately set free. In 1972 it was released in Santiago in Chile, and has since spread throughout most of the country.

### Pets turned pests

As in other countries, thousands of monk parakeets were imported to Chile as pets, until this was banned by the government in 1997. Being very adaptable birds, they quickly settled into their new home once free from captivity. Today, there are breeding groups in more than 20 cities across the country, although most are found in the central region.



Photo: <http://hometown.aol.com>

While many parrots nest in cavities in trees, monk parakeets instead build enclosed nests from woven twigs. They are highly gregarious, nesting close together to form a large social complex. They are also very noisy, and their incessant screeching, squawking and chattering often generates complaints from people living in their vicinity.

In their natural habitat the birds typically build their nests in trees, but in cities they frequently make use of electricity poles or communication towers. This sometimes results in power cuts when the nests get wet and cause short circuits, or overload transformers until they burn out. In the United States, electrical utility companies in Florida, Texas and Chicago apparently refer to the birds as 'feathered rats' because they consider them such destructive pests!

In Chile the birds are also considered a nuisance



Photo: <http://personal.inet.fi>

because they feed on berries and fruit from garden trees and shrubs. It is feared that they might cause significant losses to fruit farms if they spread from urban environments into rural areas. And since grains and seeds make up a major portion of the diet, the birds would also pose a problem for growers of crops such as maize, wheat, sorghum, rice and sunflower. Indeed, in Argentina the species has long been labelled an agricultural pest, although its reputation may be unwarranted. The damage inflicted by monk parakeets on crops is generally light, and usually has only a minor economic impact.

It is therefore still uncertain whether invasion by the monk parakeet is serious cause for concern in Chile. Nevertheless, the government implemented a monitoring programme in 2000, and is investigating potential control methods.



## The California Quail

As its name suggests, the California quail *Callipepla californica* is native to the west coast of the United States. It is a ground-nesting bird that is popular as a game species, although it is sometimes kept as a pet. It was first introduced to Chile during the 1860s by an immigrant who brought a dozen quails with him from California and kept them caged on his ranch. The birds escaped and became established in the wild. Other introductions followed, and the quail is now abundant in the dry central zone. It prefers living in agricultural fields and scrub vegetation, where it feeds mainly on seeds, but also on fruit, berries and insects. It is thought to compete for food and space with the Chilean tinamou *Nothoprocta perdicaria*.



TINAMOU Photo: [www.ism.ac.jp](http://www.ism.ac.jp)

Photo: <http://stevenmetzphotography.com>





**The red-eared slider *Trachemys scripta elegans* is a freshwater turtle native to the Mississippi River valley in the United States. It gets its name from the red stripes on the sides of the head and its habit of quickly sliding into the water if disturbed, leaving barely a ripple.**

The turtle has been introduced around the world – mainly through the pet and aquarium trade – and has established breeding populations after escaping or being released from captivity. In South America it has been recorded in a number of waterbodies in and around urban areas. There are concerns that it may compete with indigenous turtles and other aquatic animals for food and space.

### **Popular pet**

The red-eared slider is a popular pet that is relatively easy to care for, as it eats a wide variety of foodstuffs. The brightly coloured young turtles are especially sought after, but they darken with age and may become too large for home aquaria. Many people probably release unwanted pets into local waterbodies, and the animals sometimes wander away from garden ponds. In Asia, the turtles are also often released during Buddhist merit-making ceremonies.

The turtles are able to adapt to a wide variety of habitats, and easily become established in slow-flowing rivers, shallow lakes, ponds, swamps, drainage ditches and reservoirs. They prefer quiet waters with a muddy bottom and plentiful vegetation, and have an omnivorous, generalist diet. Juveniles tend to be mainly carnivorous, while adults are more herbivorous, but both will feed opportunistically on aquatic insects, snails, small amphibians and

crustaceans, and aquatic plants and algae. The turtles feed at night and spend most of the day sunning themselves, basking on rocks, logs, vegetation or banks. In fact, they sometimes flood floating birds' nests by climbing onto them, and have been reported to prey on young chicks.

### **Salmonella spreaders**

In 1975, the sale of red-eared sliders under four inches in size was banned in the United States by the Food and Drug Administration. This was because the animals were being raised in crowded, unsanitary conditions, surrounded by rotting food that became contaminated with *Salmonella* bacteria. The turtles were unaffected by the bacteria, but served as carriers of salmonellosis, causing thousands of cases of the disease in children who bought the animals as pets.

However, the turtles were still allowed to be raised for sale in other countries, and between 1988 and 1994 approximately 26 million were exported to international markets. The hatcheries now rely heavily on antibiotics to control bacterial infections, which has given rise to antibiotic-resistant strains of *Salmonella*. Apart from the resulting threat to humans, there is a risk that released or escaped turtles will spread diseases and parasites into the environment.

Many countries have banned turtle imports, mostly because of concerns about the species' impact on indigenous ecosystems. However, 3 to 4 million hatchlings are still exported from the United States every year. In some Asian countries, including China, Malaysia and the Philippines, the turtles are farmed for food.





## REPTILES TEIU LIZARD

Native to continental Argentina, Uruguay and Brazil, the teiu lizard *Tupinambis merianae* was introduced to the tiny island of Fernando de Noronha – 300 km off the north-eastern coast of Brazil – in the late 1950s. At the time, the island was being used as a military base, and two pairs of the lizard were released with the expectation that they and their offspring would help control rats and frogs. Unfortunately, the fact that the lizard is a diurnal animal while rats are active at night was overlooked!

The lizard found an abundant food supply, however, in the form of the eggs of seabirds nesting on the island. Its effect on ground-nesting birds was so severe that they were forced to move to smaller islands nearby. The combined impact of predation followed by a reduction in breeding space may well have caused a decline in the population of some bird species. In the meantime, the lizard population has steadily grown, and by 2004 was estimated at between 2 000 and 8 000 on the 17 km<sup>2</sup> island.

This example highlights the impact that a species can have once natural habitat boundaries are crossed, regardless of political boundaries.



PHOTOS: Caio Borghoff / BIOPHOTO Project





The giant African snail *Achatina fulica* is typically about 7 cm tall, but can grow as large as 20 cm and weigh as much as a kilogramme. Native to East Africa, it is now widely distributed in southern and eastern Asia, as well as many islands of the Indo-Pacific and West Indies. During the 1980s it was introduced to Brazil for *escargot* farming, and is now widespread in at least 15 of the 26 Brazilian states.

**Public nuisance**

Away from its natural enemies, the giant African snail is able to increase rapidly in numbers, and has become a destructive pest of crops and garden plants. It also feeds on indigenous vegetation, and often poses a conservation problem by altering habitat and outcompeting other snails for food. At times it may experience population explosions and become a public nuisance, hampering human movement by covering roads and paths. In addition, the



www.aphis.usda.gov

snail is a vector for disease such as eosinophilic meningitis, caused by the parasite rat lungworm that is passed to humans through eating raw or improperly cooked snails.

Although the giant African snail is a tropical species, it is capable of surviving adverse conditions – even snow – by aestivating, so it is a potential threat to countries in cooler and drier climates. While the snail has in many cases been deliberately introduced for food, medicinal use or as an ornamental species, it may also be accidentally imported by the nursery and agricultural trade when soil, plants or packaging material are contaminated with the snail or its eggs. Once introduced, the eggs are typically dispersed in garden waste and in soil adhering to construction and landscaping machinery.

**Control**

The snails are hermaphrodite – having both male and female sex organs – and after a single mating can lay up to 1 200 eggs in a year. The effectiveness of this reproductive strategy is highlighted by a case study of the snail's introduction and subsequent eradication from Florida in the United States. In 1966 a boy returning from Hawaii smuggled three giant African snails into Miami, and his grandmother released them into her garden. Three years later state authorities launched an eradication campaign – which ultimately cost over \$1 million – and by 1973 more than 18 000 snails had been found!

The success of the campaign can be attributed to the invader's early detection, as the giant African snail is extremely difficult to eradicate once established. Hand-collecting followed by proper disposal remains the safest means of control. Some programmes advocate the use of snail traps, using beer as bait. Others have incorporated poisoning with molluscicides and other chemicals, and even using flame-throwers to burn snails alive, but there are safety concerns associated with these methods. Biological control also backfired in this case. The rosy wolf snail *Euglandina rosea* was introduced to more than 20 oceanic islands and a number of Asian countries as a biocontrol agent, with disastrous consequences. While there are no indications that it has been successful in controlling the giant African snail anywhere, it has caused the extinction or decline of indigenous snail species wherever it has been introduced.

**In August 2004 a public awareness and collection campaign was launched in the Brazilian city of Manaus. Municipal workers, with the help of schools and NGOs, helped spread information about the need to control the *caramujo*, and demonstrated proper collection techniques.**

The big-headed ant *Pheidole megacephala* is a small ant, but – as its name suggests – it has a disproportionately large head. Believed to be indigenous to southern Africa, it is now distributed throughout the temperate and tropical zones of the world, as it is a ‘tramp species’ spread through trade and commerce.

In South America, a survey of three Brazilian cities revealed that the big-headed ant was the dominant ant species in residential homes. The ant is a domestic nuisance when living in close association with humans, because it invades food supplies and chews through telephone cabling and electrical wires. In farming areas it often damages plastic irrigation tubing. It also impacts agriculture by eating seeds and promoting outbreaks of insect pests such as mealybugs, which reduce crop productivity. In exchange for their sugary honeydew secretions, the ant protects the bugs from predators such as wasps and spiders, and carries the young to other host plants so that they can form new populations. At high densities the sap-sucking bugs weaken plants, and this is compounded by sooty mould that colonises the honeydew, causing canopy dieback or even death of the plant. In some areas, however, the big-headed ant is used as a biocontrol agent. In Cuba, for example, farmers distribute the ants in their sweetpotato fields and banana plantations to control weevils and other insect pests.



The big-headed ant is a serious threat to biodiversity. It displaces indigenous ant species and other invertebrates through its aggressive behaviour, often deterring natural pollinators and eliminating important food items for vertebrate populations. It preys on invertebrates and will even kill small vertebrates, such as bird hatchlings. In one study in a tropical rainforest in northern Australia, invasion by the big-headed ant was implicated in a dramatic reduction in the abundance of indigenous invertebrates.

Control measures against this invader typically rely on toxic baits and barriers. A fire management regime may also play a role, by providing an unfavourable environment for the ant or destroying entire colonies.

### The Little Fire Ant in Galapagos

The little fire ant *Wasmannia auropunctata* is native to Central and South America, but it has invaded several Pacific Island groups – including Ecuador’s Galapagos archipelago – as well as the West African countries of Gabon and Cameroon. It is also a greenhouse pest in temperate regions such as England and Canada.

In the Galapagos Islands, the ants prey on insects and spiders, reducing the abundance and diversity of these arthropods to such an extent that other predators, such as birds and lizards, may be negatively impacted. They also aid the build-up of populations of invasive species of scale insects, as they protect these sap-sucking pests from predators in exchange for their sugary excretions of honeydew. They even affect nesting behaviour and reduce the reproductive success of reptiles and birds, being known, for example, to attack the eyes and cloaca of egg-laying tortoises and to eat the hatchlings.

In 2001, an eradication programme was initiated on Marchena Island, in the north of the Galapagos archipelago. Linear transects, approximately 10 metres apart, were cut through the vegetation of the infested 20 hectares and a surrounding buffer zone of 6 hectares, and the fire ant-specific bait Amdro® (Hydramethylnon) was applied up to three times between March and October 2001. Since then, six monitoring surveys have been carried out, and no fire ants were found on the last three trips. The monitoring surveys, which involve laying thousands of sticks painted with peanut butter as bait, will continue for an additional two years to ensure eradication of any remaining populations. The Galapagos programme represents the world’s largest eradication campaign for this invasive species.





The Africanised honeybee *Apis mellifera L. scutellata* is a hybrid resulting from cross-breeding between European and African strains of honeybee. It spread rapidly after being released in Brazil in the 1950s, advancing through South and Central America at a rate of up to 450 km per year. Such swift progress and proliferation was possible because it tends to swarm more often than other honeybees, and is less discriminating in its choice of nest site.

### Origins

In 1956, Brazil's Agriculture Ministry arranged for some African honeybee queens to be imported from South Africa, with the aim of breeding a bee that was well suited to the country's hot, humid climate. The European honeybee that had been introduced into South America for honey production decades before had never performed well, being adapted to the colder and drier climate of its homelands.

The African queens were quarantined at an agricultural research station, where they were interbred with

European drones. The resulting 29 colonies of hybrid honeybees were kept in hive boxes equipped with queen excluders – devices that prevent the escape of the queen and thus eliminate the danger of swarming. In October 1957, the excluders were removed by a passing beekeeper, and the bees swarmed into the nearby forest. Within a few years, bees were reported to be attacking people and animals in the surrounding rural areas.

Before long, the Africanised bee had spread both north and south to other parts of the continent. It reached the southern limit of its invasion at approximately 34°S, although periods of mild weather allow a temporary expansion further south. In 1990 the first swarm was detected in the United States in Hidalgo, Texas. The bee has since spread to New Mexico, Arizona, California and Nevada, but its progress has slowed in recent years, suggesting that it may have reached its northern limit.



Photo: [www.invasive.org](http://www.invasive.org)

## Killer Bees

Africanised bees were dubbed 'killer bees' by the media, because their aggressive attacks have often resulted in the death of victims. They react defensively to any noise or vibration in the vicinity of the colony, swarming out in large numbers to sting intruders. Apart from the danger they present to the general public, the bees may disrupt agriculture by threatening farmworkers and livestock. There are also concerns that the bees outcompete native pollinators, potentially disturbing entire ecosystems.

It is the beekeeping industry that has been most affected by the invasion, however. Africanised bees tend to invest more in rearing brood than storing honey, and they probably cause European bees to produce less honey by competing with them for nectar resources. They often abandon hives, as they move more frequently than other honeybees. In Venezuela, for example, the rate of abandonment of Africanised bees is approximately 10%, which translates to a significant cost for beekeepers. Furthermore, bees used for pollination services must be moved into fields at night, when they are calmer and therefore less likely to attack or abscond. As compensation for having to work at night, wear heavy protective clothing, and endure a greater risk of being stung, workers demand higher wages from their employers, compounding the economic impact of this invader.

The European wasp *Vespula germanica*, also known as the German yellowjacket, is a social insect native to Europe, North Africa and temperate Asia. It has achieved an almost global distribution, however, having become established in North America, South Africa, New Zealand and Australia, as well as South America. It was unwittingly introduced to Chile in the early 1970s, and a decade later was observed for the first time in Argentina, in the province of Neuquén. It now occurs throughout northern Patagonia, where climatic conditions are similar to the species' native range, and has the potential to invade other suitable areas of the continent.

### Pesky pest

The European wasp is a destructive pest in many invaded regions. This is partly due to its aggressive nature – it has a tendency to swarm and attack intruders, stinging them repeatedly – but also because of its broad diet. It targets almost any carbohydrate or protein food, including nectar, fruit and meat – both dead and alive. It feeds on the carcasses of animals and fish, but also preys voraciously on insects and spiders. Its predatory habits, together with its ability to outcompete indigenous species for food, raise concerns about its impact on natural biodiversity.

The wasp also has an economic impact, as it causes losses to beekeepers and fruit farmers. It attacks beehives to prey on bees and steal pollen and honey, and damages soft fruits, reducing their market value and making them more susceptible to infection. In addition, it poses a threat to fruit pickers, who may be stung if they disturb the nest. Pets and livestock may also be at risk of attack. In urban areas, the wasp is a nuisance to people eating outdoors, and is particularly dangerous to those who are allergic to its sting.

### New beginnings

The European wasp typically has an annual life cycle. The colony of up to 5 000 workers dies off in late autumn, and the single queen spends the winter hibernating in a sheltered, well-insulated place. This has facilitated the species' dispersal around the world, as hibernating queens are sometimes inadvertently transported in cargo to new locations. With the arrival of warm weather in spring, the queen emerges to found a new nest close by in cavities in

soil, foliage, tree trunks, stacked material, or the roofs or walls of buildings. Chewed wood fibre is used to construct the nest, a task later taken over by the workers.

In some warm regions, such as New Zealand and Australia, the colony does not die off but persists throughout the year and becomes polygynous, made up of multiple queens and hundreds of thousands of workers.

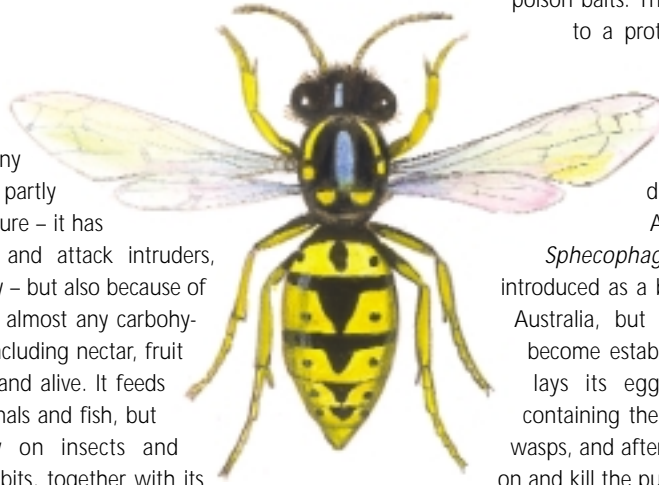
### Control

Insecticide sprays or dusts can be used on wasp nests, but protective clothing should be worn in case the colony swarms. Electric ultraviolet insect traps will kill individual wasps, but most control programmes rely on the use of poison baits. The poison Fipronil is added

to a protein bait, such as minced meat or fish, to avoid attracting honeybees.

The bait stations are positioned at regular distances on a grid layout.

A small parasitic wasp *Sphexophaga vesparum* has been introduced as a biological control agent in Australia, but does not seem to have become established. The parasitic wasp lays its eggs in cells of the nest containing the newly pupated European wasps, and after hatching, the larvae feed on and kill the pupae.



### DID YOU KNOW?

**In Chile, the European wasp causes a 10-30% loss in grape yields. It also poses a safety concern in forest reserves that are important for tourism.**



Photo: www.funet.fi

## AQUATIC INVADERS BALLAST WATER AND SEDIMENT



**Shipping is a major pathway for the introduction of marine invasive alien species. Vectors associated with ships include ballast water and the associated sediment, bilge water, and fouling of the hull and other parts of the vessel.**

In recent years, the focus of regulatory efforts has been on ballast water and sediments. It is estimated that up to 14 billion tonnes of ballast water are transferred globally each year, and between 7 – 10,000 species of marine organisms may be present in ballast water at any given time. Since most marine species include a planktonic stage in their life cycles, these include examples from virtually all taxa, from vertebrates to micro-organisms. In addition, the sediments associated with ballast water commonly harbour cysts of species such as dinoflagellates which can remain in a state of dormancy until they are deposited in a suitable environment.

In the early 1990's, in an effort to limit the transfer of

marine species via ballast water, the International Maritime Organisation (IMO) established a Ballast Water Working Group. This led to the adoption of a set of ballast management guidelines initially in 1993, with a revised version in 1997. These guidelines recommend a variety of management measures aimed at reducing the risk of alien species introductions, including the exchange of ballast water at sea, regular removal of sediment from the ballast tanks, and treatment of ballast water and sediment before discharge. The IMO has subsequently developed a legal instrument – the International Convention for the Control and Management of Ship's Ballast Water and Sediments. The Convention was adopted in February, 2004, but has yet to come into force.

The IMO, in collaboration with the UN Development Programme, and with funding from the Global Environment Facility (GEF), also initiated a programme – the Global Ballast Water Management Programme, or Globallast – to assist

developing countries implement the Voluntary Guidelines and prepare for the implementation of the Convention. The first Phase of Globallast (2000 – 2004) included 6 pilot countries: Brazil, China, India, Iran, South Africa and Ukraine. Activities under the programme ranged from a review of the legislation, to building awareness, technical training, and port surveys and risk assessments at demonstration sites.

The demonstration site for Brazil was Sepetiba Bay. The port survey was carried out in November-December 2001, and identified a number of introduced and cryptogenic species.

Regional activities have seen the establishment, in December 2003, of a Regional Ad-Hoc Group to address

ballast water issues. The 1st South American Regional Workshop on Ballast Water Control and Management and Aquatic Invasive Species was held in Brasilia, Brazil, from 26 to 28 April 2004, to adopt a Regional Strategic Action Plan (RSAP) as well as prepare the Terms of Reference for the Regional Ad-Hoc Group, with participation of delegates from Argentina, Brazil, Paraguay, Uruguay, and observers from Chile and Colombia.

A second phase of Globallast – Globallast Partnerships – was initiated in 2005. Initial plans suggest that it will build on previous activities as well as expanding into new areas.

Further information can be obtained from: <http://www.mma.gov.br/aguadelastro>



Photo: [www.flyingchair.net](http://www.flyingchair.net)



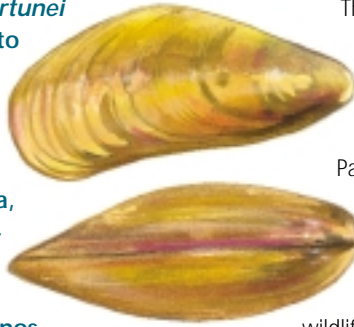
### HUMAN HEALTH IMPACTS

Apart from ecological and economic impacts, a number of the species carried in ballast and bilge waters have human health impacts. These include species which cause harmful algal blooms (HABS), as well as human pathogens such as cholera. Various strains of cholera with broad ranges have been introduced to South America, the Gulf of Mexico and other areas.

In 1991, for example, a freighter from South Asia emptied its bilges off the coast of Peru. Along with the wastewater came a strain of cholera that

reproduced well in the unusually warm coastal waters with abundant pollution. The epidemic began simultaneously at three separate seaports. The cholera bacterium *Vibrio cholerae*, made its way into shellfish and through this, to humans, spreading in an epidemic killing a reported 5 000 people. In addition, the unchlorinated water supply in Peru's cities carried the cholera strain into people's houses. This devastating epidemic extended along South America affecting more than a million people and reportedly killing more than ten thousand by 1994.

The golden mussel *Limnoperna fortunei* is a freshwater bivalve native to China and south-east Asia. During the 1960s it became established in Hong Kong, and later in Japan and Taiwan. In 1991 it was detected in South America in the Rio de la Plata, the river mouth separating Argentina and Uruguay. The mussel probably arrived in the ballast water of ships visiting the ports of Buenos Aires and Montevideo. Aided by human movements and boat traffic, it rapidly spread upstream, advancing at an average rate of 240 km per year. Today it occurs throughout the Parana River system that links Argentina, Uruguay, Paraguay, Brazil and Bolivia.



The invader's ripple effect on the food chain is especially disturbing given that the golden mussel has reached the Pantanal, a high-altitude floodplain that straddles parts of Brazil, Bolivia and Paraguay. With an area of some 150 000 km<sup>2</sup> during the wet season, this is the world's largest wetland, and is recognised as a World Heritage Site because of its rich biodiversity and abundant wildlife. Fortunately, the natural phenomenon known as 'dequada' may limit the golden mussel's establishment in the Pantanal. Concentrations of dissolved oxygen in the water decrease to some extent every year during the annual flood phase, and the mussel is unable to survive extreme low-oxygen conditions.

## Foul play

As an invader, the golden mussel has much the same impact as the zebra mussel *Dreissena polymorpha* in the Great Lakes and adjacent waterways in North America. It is a serious pest at some sites, causing massive fouling problems. It clogs the intakes, pipes and filters of water treatment facilities, industrial plants and power stations, reducing flow velocity, compromising efficiency and representing a hazard to cooling systems. By improving the habitat for micro-organisms, it results in increased surface corrosion. Decaying dead mussels pollute drinking water systems, while empty shells add to the fouling problem.

The mussel can also affect aquaculture farms by fouling cages and nets and competing with other filter-feeders for planktonic food. Furthermore, boats plying the local rivers for fishing, tourism and trade typically carry the mussel as an unwelcome passenger. Fouling on boat hulls increases drag – which reduces speed and increases fuel expenses – and may damage the hull surface, while clogging of the cooling water intakes may cause the engine to overheat, with costly consequences.

The effects of fouling by the golden mussel, together with the ongoing remedial actions required, may have a significant economic impact. Of equal concern, though, is the environmental impact of this invader. Its high reproductive capacity means that populations increase rapidly to form dense, homogenous mussel beds, resulting in reduced benthic biodiversity. Indigenous bivalves are smothered and starved as the mussels settle on top of them and compete with them for food, while other invertebrates and aquatic plants are displaced due to habitat modification. At least one fish species is known to have changed its diet by targeting the abundant mussel as its main food item, and other vertebrate predators have no doubt also altered prey selectivity in response to the invasion.

## Regional cooperation and international experience

In response to the threats posed by the golden mussel, Brazil's Ministry of the Environment established a National Task Force to combat the invader, and launched an Emergency Action Plan to prevent its further spread. A public education and awareness campaign is an important part of the plan, which is being implemented by local coordination committees.

Brazil also joined forces with its neighbours Argentina, Paraguay and Uruguay to share knowledge and experience. The Globallast golden mussel project brought together a multi-national team of researchers, and marked the beginning of regional cooperation in South America on ballast water and aquatic bio-invasion issues.

Researchers in South America are drawing upon North American experience in dealing with the zebra mussel, and several control methods are being evaluated for implementation against the golden mussel. These include mechanical cleaning, chemical and thermal treatment, carbon dioxide pellet blasting, antifouling paint application, freezing and desiccation. Treatment with a hot, chlorine solution will kill fouling mussels in water systems, and can then be used as an ongoing maintenance measure to prevent new infestations. It is important that the wastewater is not released back into the natural environment, as it will be toxic to other organisms.

Various methods of treating ballast water have been proposed, including filtration to remove ballast stowaways, or the application of biocides, ozone, ultra-violet light or electric currents to kill them. However, most of these are not practical or economically viable for application in South America at present.

Special care should be taken when transporting smaller boats, such as skiboats and yachts, from one area to another. All fouling organisms should first be scraped



off the boat and trailer well away from the water, and properly disposed of. Leaving the boat exposed on land for a week during hot, dry weather will kill most mussels, so that they will either fall off or be easier to scrape off. The hull, bilges and trailer can also be rinsed with a dilute solution of chlorine (500 cc in 10 litres of water), providing this will not contaminate any nearby water body. Water should never be transferred from one water body to another, in case it contains the microscopic larvae of the golden mussel.

#### POPULATION EXPLOSION!

South America's first record of the golden mussel was at Bagliardi, near Buenos Aires, in 1991. At that stage, the density of the population was only 5 mussels per m<sup>2</sup>, but a year later this had increased to 36 000 per m<sup>2</sup>. In 1993, the figure had more than doubled to 80 000 per m<sup>2</sup> and by 1998 had reached a staggering 150 000 mussels per m<sup>2</sup>!

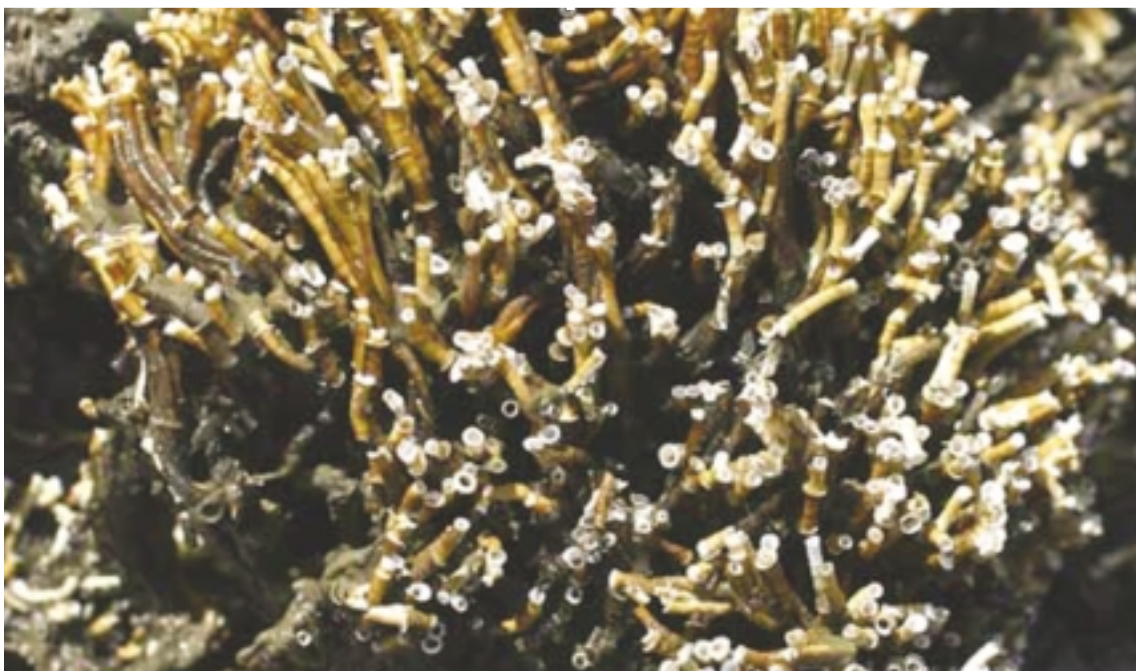
Other marine invasions on the south-east coast of South America are:

- the NE Pacific barnacle *Balanus glandula*, which colonised the Rio de la Plata during the 1960s and now occurs as an intertidal belt on rocky shores
- the Australian tubeworm *Ficopomatus enigmaticus*, which forms extensive reefs that modify estuarine ecosystems, and
- the Pacific oyster *Crassostrea gigas*, which is spreading rapidly in shallow bays.

BARNACLE Photo: [www.nwmarinelife.com](http://www.nwmarinelife.com)



OYSTER Photo: <http://home.planet.nl>



TUBEWORM Photo: [www.californiabiota.com](http://www.californiabiota.com)

The Asian clam *Corbicula fluminea* is a freshwater bivalve that is native to south-east Asia, but is now well-established in Europe, Australia, Africa, and North and South America. It was probably introduced to South America in the late 1960s or early 1970s in the ballast water of ocean-going ships that visited estuarine ports on the Atlantic coast. It then used boats plying the region's rivers to spread inland, and now occurs from Argentina's Patagonia region in the south to Venezuela in the north, including the lower reaches of Brazil's Amazon Basin.

### Biofouler

In its native range, the Asian clam is collected and cultivated for human consumption and for feeding to domestic fowl. Indeed, its introduction into North America in the latter half of the 1800s is attributed to Chinese immigrants, reluctant to forsake a favourite food. Away from its natural enemies the population was able to grow and spread rapidly, largely due to its exceptional reproductive capacity. The species is hermaphrodite – having both male and female sex organs – and is capable of self-

fertilisation, which means that a single juvenile can initiate the formation of a new colony. Colonies made up of 10 000 to 20 000 clams per m<sup>2</sup> are not uncommon, and densities as high as 131 000 per m<sup>2</sup> have been recorded in California. Clearly, there is a high potential for the Asian clam to compete with indigenous bivalves for space and food.

Of more concern from an economic viewpoint is the biofouling problem posed by this invader. In many areas where it has become established, the Asian clam clogs water intake pipes and obstructs irrigation and drainage canals, sometimes with disastrous consequences. Mitigation measures are expensive, time-consuming and often environmentally undesirable. For example, thermal regulation – using heated water to kill the clams – is often not practical, while chemical control with chlorine or bromine treatment may kill many other organisms in the vicinity. Screens and traps can be used in water systems to inhibit the entry of mature clams and the accumulation of shells, but the most effective way of avoiding biofouling problems is to prevent the introduction and spread of the species into new areas. Preventative actions include implementing ballast and bilge water control measures and limiting the clam's transport as a food source or as live bait.



Photo: www.digischool.nl



Photo: www.iisgpp.org

### NUCLEAR ATTACK!

In 1980, Asian clams clogged the water system of a nuclear power plant in Arkansas in the USA, jeopardizing its fire protection plans. The United States Nuclear Regulatory Commission shut down the plant and ordered an inspection of every nuclear plant in the country, to determine the threat to safety that fouling by this invasive alien species posed. Clams were found at 19 of 32 plants, with another 11 at risk because of the proximity of clams to the plants. Compliance with this directive cost an estimated \$4.5 million. During the 1980s, losses caused by utility and industry down-time, corrective actions and maintenance costs were estimated to be \$1 billion annually.

Source: [www.sgnis.org/publicat/nespp\\_4.htm](http://www.sgnis.org/publicat/nespp_4.htm)

Photo: www.thecookeryschool.org



The Japanese kelp *Undaria pinnatifida* is native to the north-western Pacific coasts of Japan, Korea, China and Russia. In Japan – where it is known as *wakame* – it is commercially harvested and intensively cultivated, as it is a favourite food item and a main ingredient of miso soup. Following introductions via shipping and aquaculture movements, the seaweed now occurs in parts of Taiwan, Australia, New Zealand, Europe, the west coast of North America, and the east coast of South America.

### Unwanted in Argentina

The Japanese kelp was first detected in South America in December 1992, when it was discovered on wharf pilings in the port of Puerto Madryn, in Argentina's Golfo de Neuvo. It was probably introduced in ballast water or on the hull of a cargo or fishing vessel from Japan or Korea. By 1999 it had spread more than 30 km along the shores of Golfo de Neuvo and was also found in Caleta Malaspina, 500 km to the south.

The kelp prefers sheltered waters such as bays and harbours, and occurs from the intertidal zone down to 15-20 metres depth in clear waters. It grows rapidly – up to 10 times faster than most kelps – and forms dense forests comprising up to 250 plants per m<sup>2</sup>. The forests' thick canopy reduces light penetration and water movement, leading to the exclusion or displacement of some native plants and animals due to habitat modification. In the Golfo de Neuvo, the holdfasts have overgrown and become entangled in the smaller seaweeds typical of the area, with the result that any dislodged kelp causes significant disturbance to the benthic community. Seaweed stranded on the shore reflects the impact of this invader on species composition – native seaweeds have decreased dramatically in beach casts, which are now dominated by Japanese kelp.

Apart from its effect on biodiversity, the Japanese kelp may have a negative economic impact. It is an opportunistic species prone to foul almost any substrate, but especially those near the water line. Fouling of boat hulls, buoys, mooring structures and water intake pipes necessi-

tates time-consuming and costly cleaning procedures. The kelp also poses a threat to aquaculture operations, as the kelp may foul finfish cages, scallop bags, oyster racks and mussel ropes, thereby increasing labour requirements and restricting water circulation.

### Microscopic menace

Aquaculture is in fact a major vector of introduction of the Japanese kelp – for example, it is thought that the species was first introduced to Europe with Japanese oysters imported to France. It is vital that stringent quarantine procedures be imposed on aquaculture movements, as contamination by this invader is difficult to detect. The Japanese kelp is an annual species with a lifecycle consisting of two stages. The large kelp plant, known as the sporophyte, grows during winter, reaching a length of 1-3 metres. As summer approaches, the sporophyte begins releasing spores – as many as 100 million per plant – which disperse before settling. Once all the spores have been released the sporophyte dies, but the spores germinate into microscopic male and female gametophytes. When conditions are favourable, the gametophytes produce sperm and eggs, which grow into the new sporophyte after fertilisation.

The tiny gametophytes are not visible to the naked eye, so the species can easily remain unnoticed on aquaculture products and equipment. The gametophytes can survive in darkness for months, and may form thick-walled resting stages for a long voyage as 'stowaways' in ballast water. They are also very tolerant of desiccation. This allows them to survive in crevices on boats and trailers while a vessel is in dry dock or transported overland, or on nets and ropes as a fishing boat or yacht relocates to another area. The sporophyte can also be transported long distances through hull-fouling of ships – indeed, the kelp has been known to survive voyages of more than 4 000 km!

The cryptic nature of the gametophyte stage complicates control of this invader and renders eradication unlikely, so the priority should be to inhibit its spread and prevent its introduction to new areas through proper quarantine and cleaning procedures. Some antifouling paints are effective against Japanese kelp, while high-pressure treatment with hot water would kill the gametophytes. Sporophytes should be manually removed before any spores are released, and then disposed well away from water. Removal of fouling plants should be done on land where feasible, as sections of sporophyte that re-enter the water may continue to produce spores.





The American bullfrog *Rana catesbeiana* is a very large frog weighing up to 0.5 kg and reaching a length of 20 cm. Native to the eastern parts of North America, it has been widely introduced to other parts of the world as a food crop, either for aquaculture or for harvesting from the wild. In some areas it was introduced as a biological control agent of agricultural pests, or as a pet for home aquaria and garden ponds.

### Bullfrog bully

Once introduced, the American bullfrog invariably succeeds in establishing populations in the wild. If it escapes from captivity, it is able to travel long distances overland to disperse into neighbouring waterbodies. It can flourish in areas disturbed by humans, as it tolerates the warmer temperatures and prolific aquatic vegetation typical of polluted waters. Furthermore, the eggs and tadpoles are unpalatable to fish, while the adults are generally inactive, making them inconspicuous to predators.

Once established, the bullfrog may have a detrimental impact on local biodiversity. It not only competes with indigenous frogs and toads, but is a voracious predator. It eats anything it can swallow – including other amphibians, snakes, turtles and even small birds and mammals – and is believed to be responsible for the decline of many species. The tadpoles are primarily grazers of benthic algae, and can significantly alter aquatic community structure.

Also of concern is the potential for the bullfrog aquaculture trade to facilitate the spread of diseases that may threaten wild populations of amphibians. For example, in 1999 a bullfrog farm in Uruguay experienced a mass die-off due to an outbreak of chytridiomycosis. This disease is caused by the fungus *Batrachochytrium dendrobatidis*, which has been implicated in the decimation of amphibian populations in a number of areas worldwide.

The bullfrog tends to be immobilised by bright light at night, so is usually hunted with a strong torch and then either caught or killed. Approved waterborne piscicides can be used to poison the tadpoles. The floating egg masses can also be collected for disposal, but since they sink to the bottom a day or two after laying, this method is usually impractical.



Photo: Silvia R. Ziller

## Bullfrogs in South America

- During the last few decades, a number of South American countries have begun rearing the American bullfrog to supply the lucrative trade in frogs' legs for the restaurants of the United States and Europe. Brazil, Uruguay and Argentina are currently the largest South American producers.

- The bullfrog was introduced to Colombia in 1986 for research aimed at assessing its potential for aquaculture. It was bred in captivity at Calda and Buga, but in 1990 – when the risk to native species was fully realised – the government institute Inderena issued a resolution banning its cultivation in Colombia and ordering the destruction of the experimental collections. By then it was too late, however, as the bullfrog had already become established in the wild. Today the densest populations are found in the Sonso Lagoon in the Cauca Valley and areas around Buga. The region's numerous irrigation dams and channels provide abundant suitable habitat, while the Cauca River has played a major role in the bullfrog's dispersion, by carrying eggs laid on floating masses of aquatic vegetation downstream. The bullfrog not only competes with the native cane toad *Bufo marinus* for food, but also preys on its larvae, as well as those of other amphibians.

## AMPHIBIANS AFRICAN CLAWED FROG



The African clawed frog *Xenopus laevis* is native to the cooler regions of sub-Saharan Africa. During the 1940s it was shipped around the world for use in human pregnancy tests, after it was discovered that the frogs begin laying eggs when injected with the urine of pregnant women. Laboratories began rearing the frogs in large numbers to meet the high demand, and because they proved so easy to keep in captivity, a flourishing pet trade developed during the 1950s and 1960s.

In the late 1950s, new technologies for pregnancy diagnosis were developed, and many laboratories simply released their frogs into the wild. However, the frog remains an important subject for biological research, since it produces large numbers of eggs and its transparent embryos allow for easy observation of developmental changes. Laboratory escapes, as well as intentional releases of unwanted pets and escapes from home aquaria, therefore remain a likely mode of introduction.

The African clawed frog is a highly adaptable species with a wide salinity and temperature tolerance. It can inhabit almost any natural or manmade waterbody, and is

now well-established throughout sub-Saharan Africa as well as in parts of the United States, Europe and South America. It feeds primarily on aquatic invertebrates, but also eats the eggs, larvae and adults of frogs and fish. In southern California, it is considered a threat to indigenous fish and amphibians.

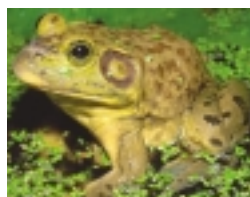
The international trade in the species is also believed to be responsible for the global dissemination of chytridiomycosis, a disease caused by the fungal pathogen *Batrachochytrium dendrobatidis*, which has been linked to the decline of frog populations in Ecuador, Venezuela, Panama, Australia, New Zealand and Spain.

The African clawed frog was introduced to Chile in 1973, when an unknown number of frogs were dumped in a lagoon near Santiago's international airport. The frog has since spread on its own – both overland and through irrigation canals – and has also been translocated by people. It now occurs in four of Chile's 13 regions, namely IV, V, VI and Metropolitan. Fortunately, the frog seems to prefer artificial waterbodies to natural systems, and has as yet shown no evidence of preying on native frog species; rather, it cannibalises its own larvae, and is also preyed upon by native birds.

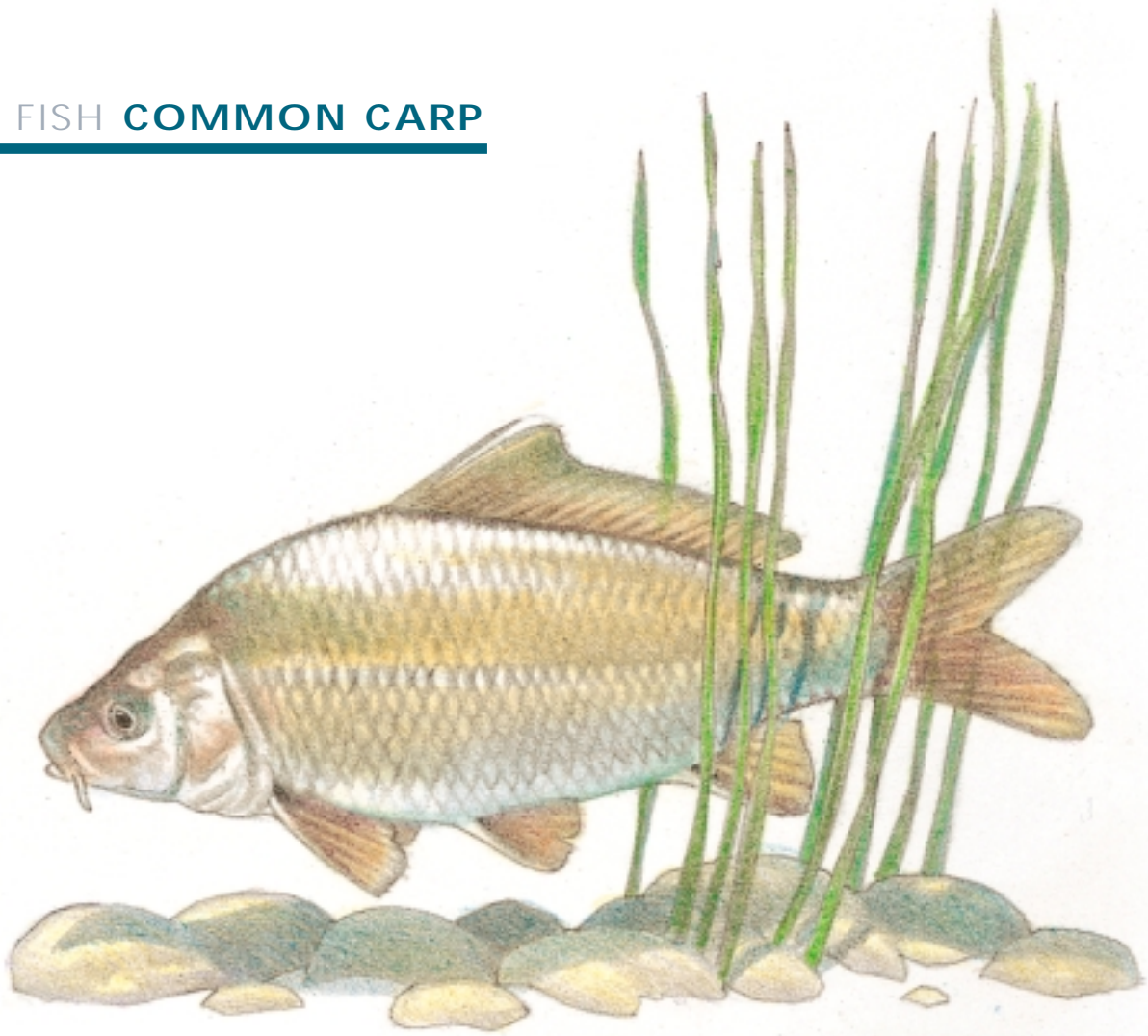
The species is still sold in pet shops in Chile, but there are calls for the trade to be banned. Many frogs are probably released from captivity when they grow too large for home aquaria, or when their owners outgrow them!

Lobos, G & Jaksic, FM 2005. The ongoing invasion of African clawed frogs (*Xenopus laevis*) in Chile: causes for concern. *Biodiversity and Conservation* 14: 429-439.

• In Venezuela, the bullfrog became established in 1998 following illegal releases into Andean waterbodies. Its area of distribution in Merida state is near the habitat of the critically endangered Venezuelan yellow frog *Atelopus carbonerensis*. In 2003, in an effort to control the bullfrog's rampant spread, the Ministry of Environment introduced a bounty system to encourage licensed hunters to target the invader. It offered 1 000 bolivars – equivalent to about US 50 cents – per dead female frog, 500 bolivars for a male, and about 15 cents per kilogram of tadpoles. By the end of that year, more than US\$1 640 had been paid for some 4 700 bullfrogs.



## FISH COMMON CARP



The common carp *Cyprinus carpio* is native to Europe, but was one of the first species to be introduced outside its natural range, and now has a global distribution. Many varieties of common carp exist – among the most popular are the scale carp *C. carpio communis*, the mirror carp *C. carpio specularis* and the leather carp *C. carpio nudus*.

The common carp has been introduced to South America as a food and ornamental fish, the earliest recorded introduction being to Chile in 1875. Today it is widely raised in commercial aquaculture farms, but is also well-established in natural systems, where it is generally regarded as a pest because of the damage it causes to freshwater habitats. Its introduction worldwide has also resulted in the spread of a number of fish parasites.

### Bottom feeder

The common carp is a member of the minnow family, and is closely related to the goldfish. However, it can grow to enormous sizes – exceeding a metre in length and reaching a weight of over 35 kg – and in exceptional cases may live for up to 50 years.

The carp is a bottom-dwelling fish, which prefers living in large, slow-flowing or standing water bodies with soft benthic sediments. It can tolerate low-oxygen conditions,

as it is able to gulp air at the surface, and can withstand temperature fluctuations and extremes. It thrives in muddy rivers and dams.

The carp is omnivorous, preferring water weeds and filamentous algae but also eating aquatic insects, snails, crustaceans, worms, snails and the spawn of other fish. It forages in bottom sediments, taking mud into the sucker-like mouth and then ejecting it after the food has been extracted.

### Muddy waters

It is because of its feeding activity that the carp is such an unwelcome invader. By uprooting plants and disturbing bottom sediments it causes severe habitat damage, to the detriment of indigenous fish and other animals. Its grubbing behaviour muddies the water, reducing light penetration and thus inhibiting the productivity of submerged plants. It releases phosphorus normally locked up within the bottom sediments, which may result in phytoplankton blooms. The increased turbidity reduces visibility, so it affects feeding by sight-dependent fish, and limits their food availability because benthic organisms are smothered by resettled sediment. Stirred-up sediment also clogs the gills and filter-feeding apparatus of aquatic organisms. All of these impacts render the habitat unsuitable for the survival of other species.

The carp's success as an invader can be attributed to its wide physiological tolerance, omnivorous diet, fast growth rate and high fecundity – a single female can lay well over 100 000 eggs per season. It also reduces the numbers of other fish predators that might prey on its young, both by eating the spawn of other fish and making the habitat unsuitable for them. As a result, carp generally monopolise water bodies to which they are introduced.

## Control

Carp are an important source of food, and support subsistence and commercial fisheries in many parts of the world. Yet, due to their destructive effects, efforts have been made to control carp in some regions, with varying success. The most basic method of physical control is to encourage people to harvest the fish, either by angling or seining. Control through water level manipulation, traps and electrofishing has also been attempted, but has proved to be too labour-intensive or costly.

The most common method of preventing carp infestation is the use of barriers, such as metal grates, electrical barriers and culverts that channel outgoing water to produce high velocities, blocking the entry of carp. However, the initial cost is high, and the structures may obstruct the spawning runs of other fish, as well as boat traffic. The effectiveness of metal grates is also limited, as they exclude adult carp but not their fry.

Chemical control usually involves the use of rotenone, a natural chemical extracted from the stems and roots of

several tropical plants. It acts by being absorbed through the gills and inhibiting oxygen transfer at the cellular level, resulting in suffocation. It can be effective for controlling small, isolated populations of carp, and is environmentally non-persistent, so restocking of indigenous fish can occur in the same season of treatment. However, rotenone is non-selective, so it also kills non-target fish and many invertebrates.

In an effort to ensure more selective action, rotenone-impregnated baits have also been tested in recent years. Pre-baiting with non-toxic bait was conducted to attract carp to a feeding station, and hence maximise the number of fish poisoned. However, as soon as rotenone was added to the food supply, the carp detected it and stopped feeding.

Australian scientists are now experimenting with a method to achieve biological control of carp by limiting their reproduction. The 'daughterless gene method' aims to genetically modify carp so that they stop producing female offspring. It is hoped that the population will become biased towards males over time, and eventually decline.

## DID YOU KNOW?

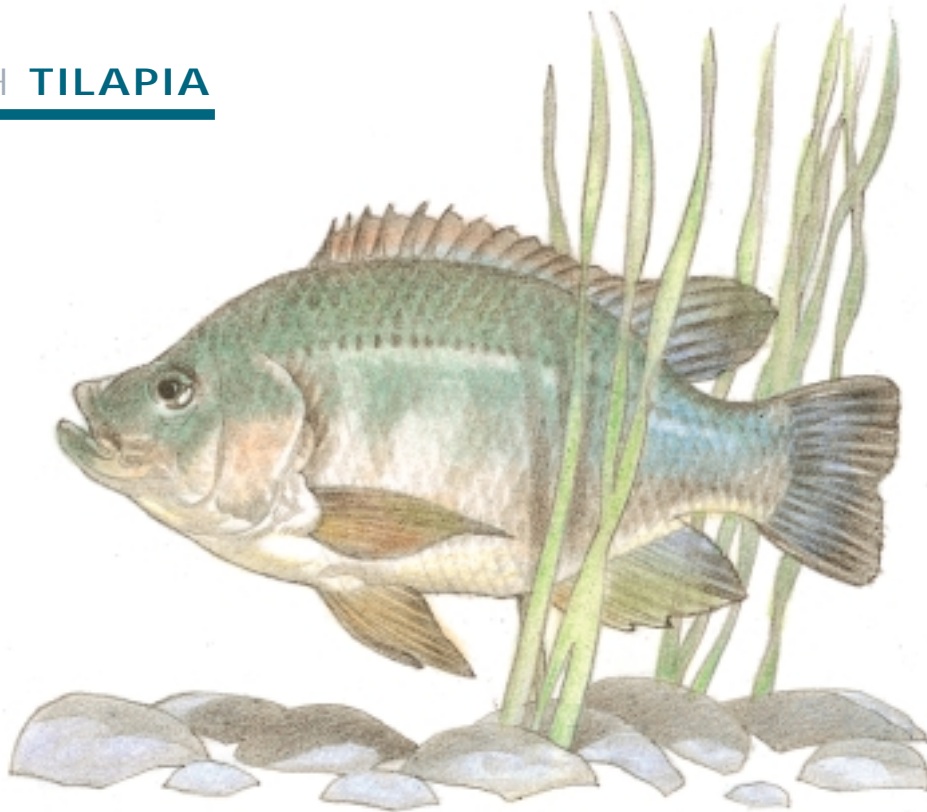
**The common carp has been particularly successful in invading Argentina's Buenos Aires province, and is estimated to occur in more than 90% of its freshwater environments. It is the only alien fish species to become established in the Salado Basin, where it comprises the largest share of fish biomass.**

## Carp Cousins

**A number of other carp species have been introduced to South America, and have established populations in natural environments. All are indigenous to parts of China and the former Soviet Union.**

- **The grass carp *Ctenopharyngodon idella* has been widely introduced for aquaculture purposes, and also as a biocontrol agent of aquatic weeds. It not only competes with indigenous fish for food, but at high densities can decimate aquatic vegetation, destroying natural habitat and resulting in dramatic ecosystem changes.**
- **The silver carp *Hypophthalmichthys molitrix* is a filter-feeder that thrives in the plankton-rich mid and upper layers of lakes and reservoirs. It is an important aquaculture species – making up 65% of carp production in Latin America in 1995 – and has also been stocked as a food fish. In some areas it has also been introduced for phytoplankton control. However, it competes with indigenous planktivorous fish and filter-feeding mussels.**
- **The bighead carp *Hypophthalmichthys nobilis* is a filter-feeder that seems to prefer zooplankton, although it will opportunistically consume phytoplankton and detritus too. It is sometimes introduced for water quality management in sewage lagoons and aquaculture ponds. Invasive populations have the potential to deplete zooplankton populations, and hence impact species that rely on plankton for food, including all larval fishes, some adult fishes, and mussels.**

## FISH TILAPIA



Tilapia are freshwater fishes belonging to the cichlid family. Some are indigenous to different parts of Africa and the Middle East, but a number of them have been introduced to other parts of the world, where they have established invasive populations in the wild. In some instances they were introduced as sportfish, aquarium fish, or even as biocontrol agents to control waterweed or filamentous algae, but in most cases they were intended for aquaculture. However, many fish escaped or were deliberately released from captivity, and subsequently established invasive populations in the wild.

Tilapia are widely distributed in South America, raising concerns about their impact on aquatic biodiversity.

### Early maturity

Tilapia are second only to carp as the most widely farmed freshwater fishes on a global scale, and by 2000 the world harvest of farm-raised tilapia had exceeded 1 200 000 tons. They are ideal species for aquaculture because they are hardy fishes, with a wide environmental tolerance, and they reach sexual maturity at a relatively young age, which allows for rapid population growth. However, in unfavourable conditions, such as limited food and space, they mature and breed at much smaller sizes than usual. This is known as stunting, and is undesirable in aquaculture as it results in large numbers of fish that are of sub-optimal size for the food market. Efforts to overcome the problem have included hybridisation between tilapia species and strains to produce all-male or sterile offspring.

These hybrid fish are commonly marketed as 'red tilapia'. Nonetheless, none of the attempts to produce monosex or infertile populations has been completely successful, so tilapia remain highly invasive.

In natural habitats, such prolific breeding means that tilapia very quickly become the most abundant fishes wherever they are introduced. Other features that contribute to the success of tilapia as invaders are their broad diet of fish, invertebrates and aquatic plants, which allows them to take advantage of available food sources, and the low mortality rate of juveniles due to parental care. All tilapia are either substrate-brooders – guarding the nest from predators and ventilating the developing eggs with their fins – or mouth-brooders, in which the eggs and fry are incubated in the mouth of one or both parents.

Tilapia impact local biodiversity because they dominate the fish biomass of waters in which they become established, and compete with indigenous species for food, habitat and breeding sites. They also displace other fish through their aggressive behaviour in defending their nests. The introduction of tilapia around the world has also facilitated the spread of fish parasites.

### Nile tilapia

As its name suggests, the native range of the Nile tilapia *Oreochromis niloticus* includes the lower Nile river basin, but the species also occurs naturally in some Rift Valley lakes, some West African rivers, and Israel. The present-day distribution is much broader, however, as the Nile tilapia has been widely introduced to other areas of Africa, south-east Asia, parts of Europe, and the Americas, with negative consequences for indigenous fish populations.





Photo: [www.risda.gov.my](http://www.risda.gov.my)

Nile tilapia is the species most commonly used for fish-farming. Taiwan is the largest exporter of tilapia worldwide, sending about 70% of its domestic production to Japan as high-quality fillets for the sashimi market and to the United States as frozen fish. In South America, production is concentrated in Colombia and Venezuela.

### **Mozambique tilapia**

The Mozambique tilapia *Oreochromis mossambicus* is indigenous to southern Africa. However, it has been widely dispersed beyond this range, having been introduced to tropical and warm temperate localities throughout the world for aquaculture, subsistence fishing and sport-fishing.

Mozambique tilapia can grow to more than 36 cm, so in the natural environment there are few predators that can target adult fish. They do, however, prey opportunistically on other fish, although they are omnivorous feeders that eat whatever is available, and seem to prefer detritus and plant matter. They have a wide salinity tolerance, being able to live and even breed in seawater, and can withstand low-oxygen conditions.

Mozambique tilapia are prolific breeders, capable of reproducing several times per year when conditions are favourable. The female incubates the eggs and fry in her



Photo: [www.infoagro.go.cr](http://www.infoagro.go.cr)

mouth, which ensures a high survival rate. This efficient reproductive strategy, together with the species' flexible habitat requirements, have allowed Mozambique tilapia to invade a variety of habitats, including dams, ornamental ponds, irrigation and stormwater channels, lakes, rivers and the upper reaches of estuaries. Since they inevitably dominate these habitats and increase water turbidity through their bottom feeding – to the detriment of indigenous fish populations – they are generally regarded as pests.

## FISH SALMONIDS



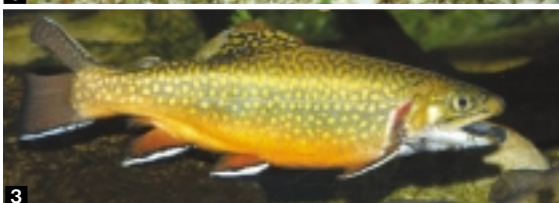
Members of the family Salmonidae – all native to the northern hemisphere – have been widely introduced to other parts of the world, including much of South America. For example, in 1904 Argentina started introducing salmonids for recreational angling, or sportfishing. Local hatcheries were established so that numerous rivers and lakes could be stocked with brood. The rainbow trout *Oncorhynchus mykiss* proved particularly popular, and was transplanted to almost any waterbody with suitable conditions. Today it is the most widespread salmonid in Argentina, found from the tropical parts – where it inhabits cold mountain streams and rivers – down to the tip of Tierra del Fuego. It has even established sea runs in the province of Santa Cruz, as has the brown trout *Salmo trutta*, which is considered a world-class sportfishery.

The rainbow trout is native to North America, while the brown trout naturally occurs in Europe as well as the

Atlas mountains of north-east Africa. These species now occur in more than 80 countries around the world, and are widely accused of impacting indigenous fish populations through competition and predation.

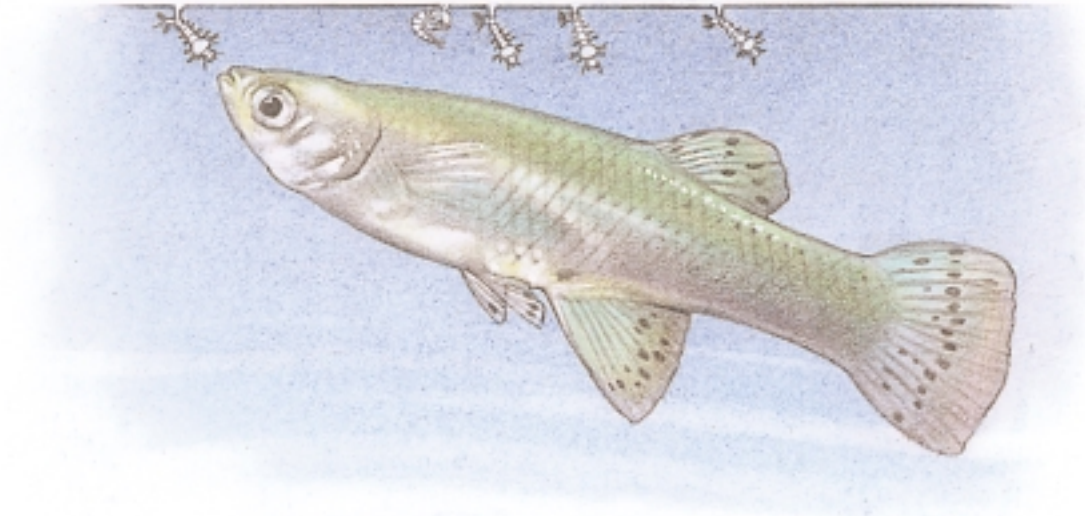
Other salmonids that have established wild populations in Argentina are the brook trout *Salvelinus fontinalis*, the lake trout *Salvelinus namaycush*, Atlantic salmon *Salmo salar* and chinook salmon *Oncorhynchus tshawytscha*.

Salmonids have also been introduced for aquaculture to supply the lucrative export market for fresh and frozen fish, smoked salmon and sushi. Chile is the principal producer, accounting for 90% of South American production and 15% of world production in 1995. The main species farmed are rainbow trout, Atlantic salmon and coho salmon *Oncorhynchus kisutch*. The cage farms are concentrated on the country's southern coast, where there are many sheltered areas. As in other countries, there are concerns about the environmental impacts of aquaculture, such as eutrophication and benthic modification.



1. BROWN TROUT Photo: <http://users.aber.ac.uk> • 2. JUVENILE COHO SALMON Photo: <http://en.arocha.org> • 3. BROOK TROUT Photo: [www.animalpicturesarchive.com](http://www.animalpicturesarchive.com)  
4. CHINOOK SALMON Photo: [www.campbeale.org](http://www.campbeale.org) • 5. LAKE TROUT Photo: [www.huntingandfishingjournal.org](http://www.huntingandfishingjournal.org) • 6. ATLANTIC SALMON Photo: <http://training.fws.gov>

## FISH MOSQUITO FISH



The mosquito fish species *Gambusia affinis* and *G. holbrooki* are indigenous to the south-eastern parts of the United States and northern Mexico. Starting in about 1900, however, they were distributed around the world for the biological control of mosquito larvae. Well-established populations of one or both species now occur in approximately 70 countries, including many in South America.

### Efficient reproduction

The mosquito fish is a small but hardy fish, able to survive in waters with low oxygen levels, high salinities and high temperatures. Its wide tolerance range, together with its efficient reproductive strategy, allows it to multiply rapidly and dominate habitats into which it has been introduced. Indeed, individual populations have been recorded to increase from 7 000 to 120 000 in just five months! The female incubates the eggs internally and gives birth to live young – ensuring a better survival rate – and several broods can be produced per year, each made up of 50 to 100 young. This high breeding rate makes it difficult to eradicate the fish once it is established.

The mosquito fish is regarded as a pest in many countries, as it not only competes with indigenous fish species for zooplankton food, but also preys on their eggs and larvae. Owing to these tendencies, it is held responsible for the decline of various species of indigenous fish. Furthermore, there is evidence that it prefers feeding on macro-invertebrates rather than mosquito larvae. By reducing populations of indigenous fish and macro-invertebrates that help control mosquito larvae naturally, the mosquito fish may actually exacerbate the mosquito problem.

### DID YOU KNOW?

In 1943, 20 000 mosquito fish were introduced to Argentina for mosquito control. They bred rapidly, and were spread by floods and by their use as live bait. Today they are widely distributed in the central parts of the country.



*Gambusia affinis* Photo: [www.canal-martiniere.org](http://www.canal-martiniere.org)



*Affinis* Photo: [www.bishopmuseum.org](http://www.bishopmuseum.org)

## INSECT PESTS

Some of the most important invasive alien species in South America are insect pests of agriculture. Their destructive feeding habits can cause massive crop failure, with crippling socio-economic consequences.

### INSECT PESTS COFFEE BERRY BORER

The coffee berry borer *Hypothenemus hampei* is a tiny black beetle, thought to originate from Central Africa. Its distribution now includes most of the major coffee-producing nations of Africa, Asia, and Central and South America.

The female beetle bores into immature coffee berries to lay eggs, and after hatching the larvae feed on the bean contents. The damaged berries turn brown and some fall to the ground, while others are retained on the tree until harvesting. Both scenarios result in a drop in yield, while those that are harvested and inadvertently ground up with the rest of the crop degrade coffee quality.

The best results are achieved with an Integrated Pest Management approach, using biological control agents and fungal pathogens, together with appropriate cultural practices and the judicious use of agrochemicals where necessary. The parasitic wasps *Cephalonomia stephanoderis* and *Prorops nasuta* – native to Africa – have been widely introduced to Latin America as biocontrol agents, while *Beauveria bassiana* is the most promising fungal

pathogen, especially in Colombia's humid environment. Many farmers use the insecticide spray endosulphan, although this is not cost-effective as the pest is protected deep inside the berry for much of its lifecycle. In some areas, the coffee berry borer has developed resistance to the chemical. Endosulphan is also hazardous to workers' health.

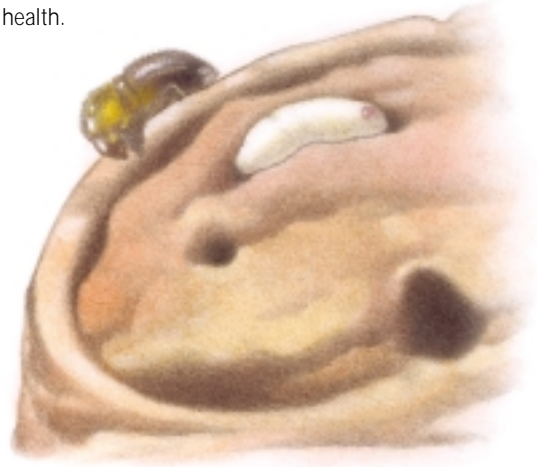
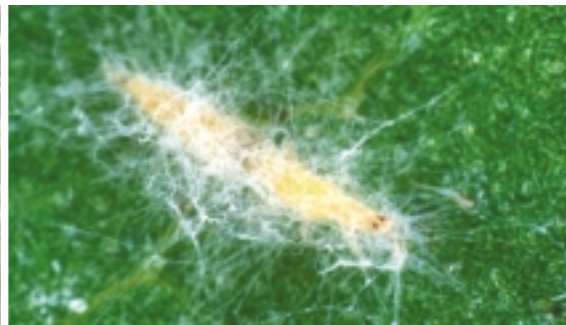


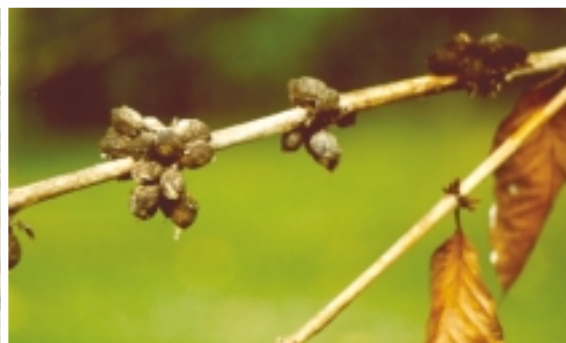
Photo: [www.ars.usda.gov](http://www.ars.usda.gov)



*Beauveria bassiana* Photo: [www.biocontrol.ucr.edu](http://www.biocontrol.ucr.edu)



Coffee harvest in Nicaragua Photo: [www.toursnicaragua.com](http://www.toursnicaragua.com)

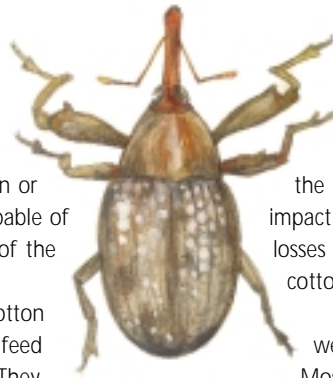


Beans attacked by beetle

## INSECT PESTS COTTON BOLL WEEVIL

The cotton boll weevil *Anthonomus grandis* is native to Mexico or Central America, but has used the cotton trade to spread to both North and South America. The boll weevils may be transported to new regions in cotton seeds or bolls, raw cotton or various cotton products. The adults are capable of flying long distances, facilitating dispersal of the species after introduction.

The female weevil lays her eggs in cotton flower buds, and after hatching the larvae feed inside the bud or boll for up to two weeks. They then pupate and develop into adults, which chew their way out. The adults feed on cotton plants for up to a week before mating and laying eggs. The entire cycle takes about 17 days under ideal conditions, with six or seven generations produced per year.



Feeding damage by the larvae causes cotton buds to turn brown and fall off. The plant is also vulnerable to attack by boll-rotting fungi, which enter through the egg and feeding punctures made by the adults. Overall, the pest has a significant impact on cotton production by causing crop losses as well as a reduction in the quality of cotton fibre.

In the United States, controlling the boll weevil costs some US\$75 million annually. Most success is achieved using an integrated approach drawing upon a variety of control methods. These include cultural practices and planting of resistant cultivars, timely application of chemical defoliant and insecticides, pheromone-trapping, release of sterile males and biological control.

Cotton field Photo: [www.amalthys.com](http://www.amalthys.com)



Photo: [www.invasive.org](http://www.invasive.org)

## INSECT PESTS COTTONY CUSHION SCALE

The cottony cushion scale *Icerya purchasi* is native to Australia, but is now widespread in the tropical and subtropical of the world, and also occurs in greenhouses in colder countries. It attacks more than 200 plant species, including acacias and brooms, but is a particularly serious pest of citrus. Feeding damage by these sap-sucking insects causes defoliation and fruit drop, while their excretions of honeydew are colonised by sooty mold.

The cottony cushion scale is widely distributed in South America, and in 1982 it was reported for the first time in Galapagos, on the island of San Cristóbal, having been introduced on ornamental plants brought from the mainland. It spread to several other islands in the archipelago, but it was only in 1996 – when serious outbreaks of the pest occurred – that conservation organisations were alerted to the threat it posed. Surveys revealed that the scale insect had killed endangered plants and may have caused local extinctions of several host-specific endemic moths and butterflies.

The ladybug *Rodalia cardinalis* had already been used

successfully in many other parts of the world for the biological control of cottony cushion scale, without any adverse affects. Nevertheless, a six-year research programme was undertaken to ensure that the biocontrol agent would not feed on non-target species, or have any other detrimental environmental impacts in the Galapagos. In 2002, the first ladybugs were released, and to date more than 1 500 have been distributed to priority areas in the archipelago. Preliminary results from a post-introduction monitoring programme suggest that they have successfully controlled the scale insect on several islands.



Photo: <http://imgagedb.calisnet.arizona.edu:8080>

## INSECT PESTS EUROPEAN WOODWASP



The European woodwasp *Sirex noctilio* is the pest that poses the greatest threat to pine plantations in South America. It was first reported on the continent in 1986, when it was detected in Uruguay, and is now widespread in that country as well as the three major pine producers – Brazil, Chile and Argentina. The pest has also invaded South Africa, Australia and New Zealand.

The female woodwasp uses her ovipositor to drill into the wood of pines and other conifers. Along with her eggs, she deposits a mixture of mucus and fungus. The mucus inhibits the movement of sugars and water within the trunk, causing the foliage to wilt and making conditions suitable for the spread of the fungus. The fungus, *Amylostereum areolatum*, dries out the wood and makes it easier for the larvae to digest as they tunnel through the trunk. The fungus also serves as a nourishing food for the growing larvae, until they pupate inside the tree. Later the adult wasps bore their way out, leaving large round

emergence holes in the bark.

Apart from the damage caused to the timber by the tunnelling larvae, the mucus and fungus weaken the tree and cause a drastic reduction in stem growth. The foliage yellows and may eventually fall off, and under severe attack the tree may die. Most damage occurs in over-crowded plantations, as suppressed and malformed trees are particularly susceptible. Management practices include regular thinning to reduce competition between trees and encourage vigorous growth, and timely removal of felled trees that would be likely to attract ovipositing woodwasps. Since pruning temporarily weakens a tree, it should be avoided in summer when woodwasps are abundant.

Natural enemies and introduced biocontrol agents are effective against the woodwasp in some areas. These include the nematode *Deladenus (Beddingia) siricidicola* and parasitic wasps such as *Ibalia leucospoides* and *Megarhyssa nortoni*.



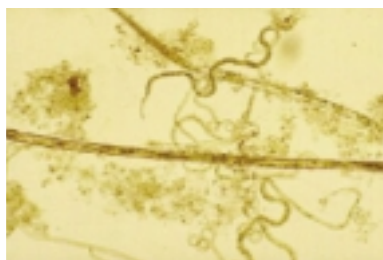
FUNGUS *Amylostereum areolatum* Photo: <http://houby.humlak.cz>



WOODWASP Photo: Charles Griffiths



WOODWASP LARVAE Photo: [www.invasive.org](http://www.invasive.org)



NEMATODE Photo: [www.inta.gov.ar](http://www.inta.gov.ar)



*Megarhyssa nortoni* Photo: [www.uq.net.au](http://www.uq.net.au)

## INSECT PESTS CODLING MOTH



Photo: www.hisek.com

The codling moth *Cydia pomonella* is native to Eurasia, but now occurs in most of the apple-growing regions of the world. Its larva is the familiar 'apple worm' that tunnels through the flesh of the fruit. Apart from apples, this pest also affects pears, plums, peaches, apricots and walnuts. In South America it is particularly problematic in Chile and Argentina, and phytosanitary controls have been put in place in an effort to prevent its spread to neighbouring countries.

The female moth lays her eggs on leaves near fruit, or on the fruit themselves, and after hatching the larvae bore through the fruit surface. They feed near the surface for a while, and then tunnel into the core. As they feed, their excrement, known as frass, is pushed out behind them,

and accumulates around the entrance hole. They feed on the core seeds and surrounding flesh for up to a month, before emerging from the fruit to spin a cocoon in a sheltered place.

The damage caused by the tunnelling larvae greatly reduces the market value of the fruit and its storage quality, often resulting in rejection of fruit loads at delivery. Sometimes the fruit surface is seen to be covered with numerous 'stings' – these are made by larvae boring into the flesh for a short distance before dying or emerging to enter at another site.

A variety of methods are available for controlling codling moth, with best results achieved using an Integrated Pest Management approach. The pest has developed resistance to organophosphate insecticides in many countries, so mating disruption using pheromone lures is usually the preferred strategy. Cultural practices and biocontrol are also effective. The parasitic wasp *Trichogramma platneri* attacks codling moth eggs, so its release should be timed to coincide with egg-laying by the pest. This can be achieved with the help of pheromone traps to monitor the codling moth population.



Photo: www.rodeland.de



PARASITIC WASP *Trichogramma platneri* Photo: <http://intern.nhm.ac.uk>



Photo: www.invasive.org



# SOUTH AMERICA invading

## **Invasive Alien Species originating from South America**

While numerous invasive alien species occur in South America, many of the region's own plants and animals have invaded other parts of the world. The following pages highlight a small selection of these 'exports'.



## Water hyacinth



The water hyacinth *Eichhornia crassipes* is considered the world's worst invasive aquatic weed. Indigenous to the Amazon Basin of South America, it was widely introduced as an ornamental plant, and today occurs in more than 50 countries on five continents. The plant thrives in still and slow-moving waterbodies that have become nutrient-enriched through eutrophication. Dense mats of water hyacinth now blanket many natural and manmade waterbodies around the globe.

Water hyacinth infestations are associated with a variety of socio-economic and environmental impacts. Dense mats that block waterways inhibit boat traffic, with the result that they disrupt trade, fishing and recreational activities. Agricultural production can also be affected as the plant is a weed of wetland crops such as rice and jute, and often clogs irrigation canals and pumps. The mats threaten hydroelectric power schemes, and increase siltation of rivers and dams by impeding water flow and trapping particles in suspension. They adversely affect the

quality of drinking water, and pose a health risk by creating conditions suitable for mosquitoes and other vectors of disease.

The thick mats reduce light penetration into the water, which causes a decline in phytoplankton concentrations that support the zooplankton-fish food chain, resulting in ecosystem changes. Rotting material depletes oxygen levels in the water, further impacting aquatic biodiversity. In addition, vast quantities of water hyacinth can damage road and rail bridges when swept downriver during floods.



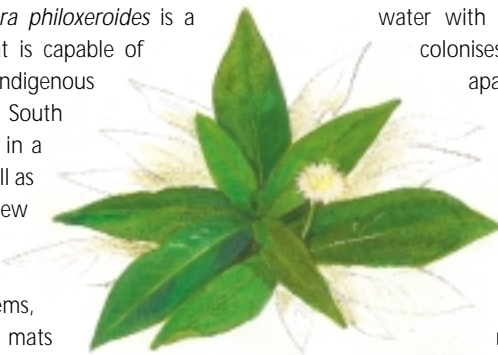
Photo: Charles Griffiths

## Alligator weed

The Alligator weed *Alternanthera philoxeroides* is a fast-growing perennial herb that is capable of growing on land and in water. Indigenous to the Parana River region of South America, it has become invasive in a number of Asian countries, as well as parts of the United States, New Zealand and Australia.

The aquatic form of alligator weed has hollow, floating stems, which interweave to form dense mats on the water surface. These clog waterways and restrict flow in irrigation and drainage systems, with the result that they increase sedimentation and the risk of flooding. The mats frequently damage pumping equipment and sometimes affect hydroelectric power production. They impede fishing activity and recreational use of water bodies, provide habitat for mosquitoes, and are aesthetically unappealing. They also have a variety of ecological impacts, as they outcompete and displace indigenous plants, reduce water quality, prevent light penetration into the water and inhibit gaseous exchange at the air-water interface.

Alligator weed grows prolifically in nutrient-rich environments, and in flowing systems can tolerate brackish



water with salinities as high as seawater. It colonises new areas when the mats break apart and float downstream, and can spread onto land when its horizontal stems grow up banks and into moist soil.

The terrestrial form of alligator weed produces solid, rather than hollow, stems, as well as underground rhizomes that can reach a metre in length. In unfavourable conditions the aboveground parts of the plant may die off, but the underground rhizomes and stems can remain viable and resprout at a later stage.

On land, alligator weed is a serious threat to agriculture. It is a major weed in rice paddies, reducing production by 20-63% in China. It also causes significant losses in other crops, including sweet potato, lettuce, wheat, corn, cotton, soybean and peanuts. It infests orchards, tea plantations, mulberry fields, and medicinal and herbal crops, while dense growth along banks can restrict access to water by livestock. In addition, the weed is toxic and can cause blindness of livestock, as well as skin photosensitisation in light-pigmented cattle, resulting in cancerous lesions.

## Mile-a-minute weed



The mile-a-minute weed *Mikania micrantha* is so named because of its incredible growth rate. Shoots have been reported to lengthen by as much as 27 mm per day, and within a few months an individual plant can cover more than 25 square metres. The plant is a problem weed throughout the warm, humid region of south-east Asia and many of the surrounding Pacific Islands, as well as West Africa.

Mile-a-minute weed was widely introduced as a cover crop and garden ornamental, and was able to spread rapidly because of its efficient reproduction – a single plant can produce up to 40 000 seeds per year. The small, black seeds have a tuft of white bristles at one end to facilitate their dispersal by wind, or by adhering to clothing and animal fur. The plant also reproduces vegetatively, each node of the stem being able to produce roots on contact with



the soil. This allows the plant to regenerate from small fragments.

The mile-a-minute weed thrives in open, disturbed areas, so it rapidly overgrows abandoned areas and is frequently found growing rampantly along roadsides. More serious, however, is its presence in plantations and forests, where it is a major pest. The weed climbs up other plants to reach the sunlit tree canopy, smothering the host plants in the process and depriving them of light needed for photosynthesis, as well as competing with them for nutrients and water. The weed also has allelopathic properties, releasing substances that inhibit the growth of other plants. As a result, it negatively impacts biodiversity in natural areas and production in agricultural and forestry areas.

The weed is especially problematic in tea crops in India and Indonesia, and rubber plantations in Sri Lanka and Malaysia. However, it also increases the cultivation costs of oil palm, pineapple, banana and cocoa, as it necessitates ongoing labour-intensive control efforts. Timber and pulp production in teak and other commercial forestry operations are also negatively impacted by the weed.

## Chromolaena

*Chromolaena odorata* – commonly called chromolaena, triffid weed or Siam weed – is one of the worst invasive plant species in the humid tropics and subtropics of the world. Its native range extends from Florida in the United States to northern Argentina, but it has invaded south-east Asia, parts of Oceania, and West, Central and Southern Africa. It is a major threat to biodiversity, agriculture and human welfare.

Chromolaena occurs as both a shrub standing at least 3 m tall in the open, and as a scrambler reaching a height of 10 m among trees. It grows rapidly and produces massive quantities of light, hairy seeds – more than a million per plant – which are dispersed by wind and water and by adhering to animals, humans, vehicles and machinery. The plant thrives on disturbed land and forms dense thickets that smother indigenous vegetation, reducing biodiversity. The thickets also represent a fire hazard, as the plant's leaves contain highly flammable oils and alkaloids that increase the intensity of fire.

Chromolaena decreases agricultural productivity by

invading subsistence food gardens, cultivated crops, and young or neglected plantations of tobacco, cocoa, coconut, rubber and oil palm. In some areas it impacts commercial forestry operations, both by suppressing the growth of young trees through competition and by allowing fire to penetrate deeper into plantations. It also reduces grazing for livestock by invading pastures. In addition, the leaves cause acute diarrhoea of cattle when browsed, and skin rashes and irritation in some people after contact.

In South Africa, chromolaena is mainly considered a threat to conservation and ecotourism, as it has primarily invaded natural areas. It reduces the biodiversity of grassland, savanna and forest, and compromises game-viewing in nature reserves and national parks.



## Lantana



*Lantana camara* is indigenous to South and Central America, but was widely introduced as an ornamental plant and is now considered a weed in more than 50 countries worldwide. It forms dense thickets that displace natural communities and compromise agricultural productivity.

Lantana is a highly variable species, with hundreds of different cultivars that differ in appearance and in their tolerance to environmental conditions. The plant may occur as a compact shrub or a scrambler more than 5 m high, and is often used as a hedge plant because it forms impenetrable barriers. However, it is this quality that makes it such a menace when it invades agricultural land and forestry plantations. The thickets disrupt access of livestock to grazing and water, interfere with farming and forestry activities, and increase the intensity of fire. By encroaching onto pastures, they reduce the carrying capacity and

productivity of agricultural land. Lantana is also a weed in a variety of crop fields and plantations, including coffee, cotton, coconuts, oil palms, rubber, bananas, pineapples and sugarcane.

Furthermore, the entire plant is toxic, and ingestion of the leaves and fruit can poison cattle and sheep, exhibiting as increased sensitivity to sunlight. The soft skin of the nose, eyes, ears and lips become covered in sores that make eating and breathing painful, causing the animals to lose condition or even die. In some areas, lantana thickets provide a breeding ground for mosquitoes and tsetse flies, which are vectors of diseases such as malaria and sleeping sickness.

Little else can grow in lantana thickets because the plant is allelopathic, releasing chemicals into the soil to prevent other species from germinating. As a result, the thickets reduce plant biodiversity and change the composition of associated animal communities. In addition, the absence of groundcover results in increased erosion, particularly on steep slopes.

Lantana is able to spread rapidly once introduced to an area as the seeds are widely dispersed by birds, which eat the fruit, and are sometimes also washed from infested areas during floods, causing sudden invasions downstream.

## Brazilian peppertree

The Brazilian peppertree *Schinus terebinthifolius* is indigenous to Brazil, Paraguay and Argentina, but has become naturalised in at least 20 countries worldwide, after being introduced as an ornamental species. It is a decorative shrub or small tree with dark, shiny leaves and bright red fruits that resemble those of holly, so it is also known as the Christmas berry. The leaves emit a peppery smell when crushed, but the plant can cause allergic reactions in people sensitive to the sap or pollen. The fruits are eaten by birds and mammals, which facilitates dispersal of the seeds.

The peppertree is an aggressive invader that quickly becomes established in disturbed areas, such as roadsides, old fields and canal banks, and especially thrives in areas cleared or drained for farming. It also invades natural habitat, however, including mangroves, coastal plains and barrier islands. It forms dense thickets that outcompete other plants for light and space, and displace animals. For example, in the mangroves of



southern Florida the thickets destroy foraging areas for herons, egrets and other water-birds.

The peppertree was first introduced to Florida in the mid 1800s, but it only became a problem plant a century later. In the late 1950s a single peppertree was recorded in the Everglades National Park. By the 1980s the species covered some 90 000 acres – amounting to 10% of the park area – mainly in pinelands and mangrove swamps. Today it has infested 800 000 acres in Florida, extending from north of Lake Okechobee to the Everglades.

The peppertree is considered a noxious weed in Florida and Texas, and also in Hawaii, where it is widely distributed in lowland areas. In the United States the species also occurs in California, Louisiana and Arizona, as well as Puerto Rico and the Virgin Islands.

## Nutria



The nutria *Myocastor coypu*, also called the coypu, is a large, semi-aquatic rodent with webbed hind feet. It is indigenous to South America, but was introduced to North America, East Africa, Europe and Asia for its thick, soft fur. It has established large feral populations in some areas, and is considered a pest because of its burrowing and feeding habits.

After being introduced to countries outside the species' natural range, nutria were either released into the wild for subsequent recapture, or raised at fur farms, from where some probably escaped. Many were also deliberately released from fur farms after the demand for fur declined. Being able to adapt to a wide variety of environmental conditions, they soon made themselves at home in local ponds, rivers, swamps and drainage canals.

Nutria live in burrows that they dig in vegetated banks next to water, although sometimes they use those abandoned by other animals. They are herbivores with an enormous appetite for plants, eating approximately 25 %

of their body weight per day. At high densities their feeding can significantly impact natural plant communities. In some places they have even converted dense stands of reed to open water, destroying the habitat of wetland birds. They also increase erosion by digging up roots and underground tumours, which help to bind the soil together.

Furthermore, nutria cause considerable damage to crops such as rice, sugarcane, corn, soybean and vegetables, as well as some fruit trees. Their burrowing also weakens the banks of rivers, dams and irrigation canals, and may undermine building foundations and road beds. In the United States, nutria are most abundant along the Gulf Coast of Louisiana and Texas, where they frequently damage water-retaining levees in fields flooded for rice and crawfish production, as well as flood-prevention levees that protect low-lying areas. The animals also tend to gnaw on wooden structures with their large incisors, damaging buildings and jetties.

## Armoured catfish

The armoured catfish *Hoplosternum littorale* is widely distributed in South America, occurring in many still and slow-moving waterbodies east of the Andes and north of Buenos Aires. In 1995 it was discovered in Florida in the United States, possibly having been introduced through

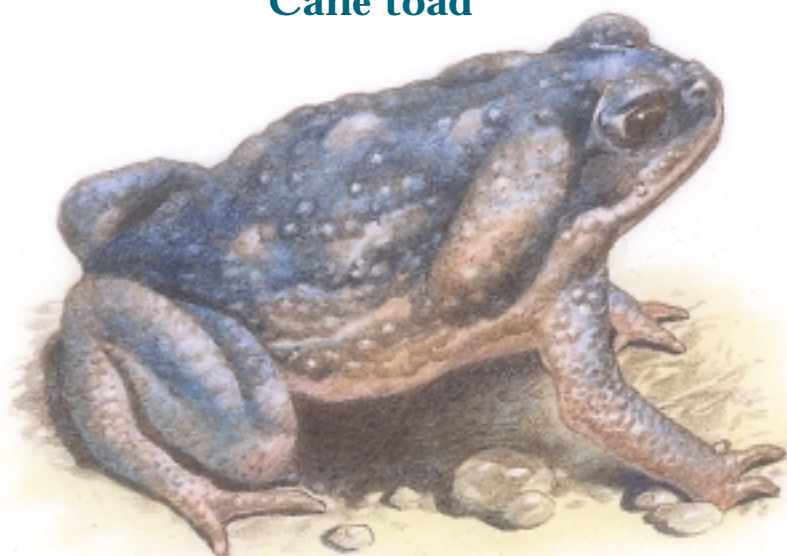


Photo: <http://jonahsaquarium.com>

the aquarium trade. It has since spread to several of the state's drainages, and there are concerns that it might invade many natural wetlands and coastal marshes. The species has a wide salinity tolerance and can withstand polluted waters rich in hydrogen-sulphide. In its native range it typically occurs in warm, low-oxygen waters, being able to supplement its oxygen intake by breathing air through intestinal epithelia.

The impact of the catfish's invasion is largely unknown, but the aggressive behaviour of breeding males might displace native fish species. Furthermore, the catfish feeds heavily on benthic invertebrates, algae and detritus, so it might alter community structure and compete with native fishes for food.

## Cane toad



The natural range of the cane toad *Bufo marinus* extends from southern Texas in the United States to the Amazon Basin in South America. The toad was widely introduced elsewhere as a biocontrol agent of insect pests in sugarcane and other crops, and was able to spread rapidly because it has a wide environmental tolerance, eats almost anything, and has few natural enemies. Today it is considered invasive in Florida, Australia, Japan, Papua New Guinea, the Philippines and many of the world's islands, particularly in the Caribbean and the Pacific.

The cane toad is one of the world's largest toads, with an average length of 10-15 cm, although individuals as big as 24 cm have been recorded. It feeds mainly on insects, but also eats worms, snails, smaller amphibians, reptiles and mammals, carrion, and even household scraps and pet food. It lives on dry land but needs shallow, still or slow-flowing water to reproduce. In fact, it is able to breed in highly saline water, which accounts for the species name '*marinus*' and the alternative common name, 'marine toad'.

The toad is only active at night: during the day and in cold or dry weather it shelters in moist areas under leaves, stones or debris, or burrows into loose soil. Although its natural habitat is tropical forest, in its introduced range it prefers living in close association with people. In rural areas it is commonly found in villages and cleared areas, while in urban environments it readily takes up residence in gardens, ponds, drainpipes and piles of rubble. It is generally an unwelcome visitor, partly because its loud calls keep people awake at night!

More importantly, however, the toad can poison pets – in Hawaii up to 50 dogs die every year after mouthing cane toads. If the toad is threatened, paratoid glands behind the eardrums ooze a venomous secretion that may cause cardiac arrest if ingested. The toad can also squirt a

fine spray of the secretion at attackers up to a metre away. The venom is absorbed through the mucous membranes of the eyes, nose and mouth, causing painful inflammation and even temporary blindness. The eggs and tadpoles of the toad are also poisonous, and people have apparently died after eating soup made with the gelatinous eggs.

Apart from the threat to humans and their pets, the cane toad may poison and injure other animals that prey on the adults, tadpoles or eggs, such as snakes, iguanas and crocodiles, although most seem to be able to tolerate low levels of the toxin. Some birds are known to rip open the toad's soft belly and eat only the mildly poisonous internal organs.

With its enormous appetite for insects, the cane toad probably also impacts indigenous wildlife by competing with other insectivorous animals for food. Indeed, in Australia it eats such large quantities of honeybees that it presents a management problem for beekeepers! It also preys on and competes with indigenous frogs and toads for food and breeding habitat.

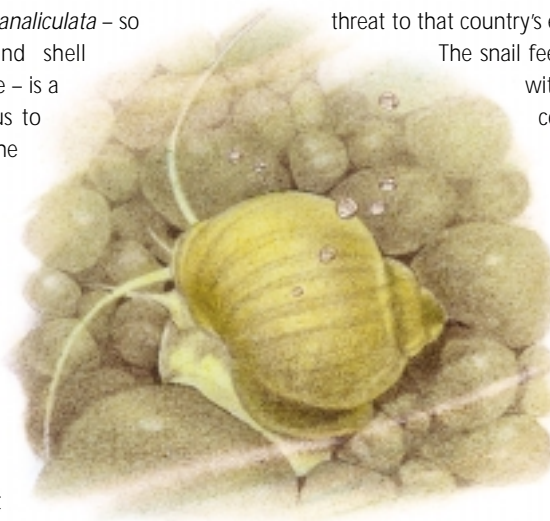


## Golden apple snail

The golden apple snail *Pomacea canaliculata* – so named because its large round shell resembles a golden delicious apple – is a freshwater snail that is indigenous to South America. It has invaded the southern parts of the United States as well as Hawaii, where it is a major pest of taro cultivation. However, its impacts are most severely felt in south-east Asia, where it is widely known as the golden kuhol.

The golden apple snail is thought to have initially been introduced to Taiwan in 1980 through the aquarium trade, but it was subsequently promoted as a high-protein food for both humans and farm animals. In 1982 it was introduced to the Philippines for snail-farming, and spread rapidly after escaping into waterways. In addition, many snail farms were abandoned after a market failed to develop because consumers did not like the taste of the snail. Within a few years the snail had become a major pest of rice; indeed, by the early 1990s, rice farmers considered it to be their greatest pest problem. Today approximately half of the country's 3 million hectares of rice lands are infested, causing huge production losses.

The species has since spread throughout south-east Asia and is now on the verge of entering India, posing a



threat to that country's extensive rice-growing areas.

The snail feeds on young rice seedlings, with large adults being able to consume up to 25 per day.

This necessitates replanting of seedlings two to four times per crop season, which is not only costly and labour-intensive but also significantly reduces yield.

The golden apple snail also eats a wide variety of other plants – preferring the young, soft parts – as well as decomposing organic

matter. By feeding heavily on aquatic vegetation it probably impacts indigenous fauna through habitat modification and competition. It has already been implicated in the decline of south-east Asia's native species of Pila apple snails.

The snail is a hardy species, being able to tolerate polluted water and low oxygen levels. It can also aestivate during the dry season, remaining buried in moist soil with its operculum closed. The bright pink eggs are laid just above the water surface; people often collect them and take them home as a delicacy, which facilitates the species' spread.

## Argentine ant



The Argentine ant *Linepithema humile* has spread from its native range in South America to parts of all other continents except Antarctica. Due to its tendency to associate with humans, it has been transported over large distances in food, rubbish, building material and cargo containers. Indeed, many of the introductions to Africa, North America and Europe in the early 1900s occurred when the ant stowed away in merchant ships carrying coffee and sugar from Brazil and Argentina.

The ant was first recorded in Cape Town in 1908, and may have been introduced in horse fodder imported from Argentina for the British cavalry during the Anglo-Boer war. It has invaded the Cape's world-renown fynbos biome, where it is negatively impacting biodiversity by interfering with seed dispersal and pollination. Many fynbos species rely on ants to disperse their seeds, providing in exchange a nutrient-rich food body – called an elaiosome – attached

## Cassava green mite

The cassava green mite *Mononychellus tanajoa* is a major pest of cassava, a starchy root crop that is a staple food for more than 200 million people in sub-Saharan Africa. It is an alien invader in Africa, being native to South America, the ancestral origin of cassava. The first outbreak in Africa occurred in Uganda in 1970, after which the pest spread rapidly to more than 25 countries throughout the cassava belt, causing an estimated 30 to 50% reduction in yield.

Fortunately, the cassava green mite is now being brought under biological control. The predatory mite *Typhlodromalus aripo* was introduced from north-east Brazil to Benin in 1993, and is now established over more than 400

000 km<sup>2</sup> in a dozen countries, mostly in West Africa. The biocontrol agent spreads about 12 km in the first season after introduction, and as much as 200 km in the second. Once established, it reduces green mite populations by half and increases cassava yields by about one third.

A related species, *T. manihoti*, shows promise as a biocontrol agent in humid areas, as it is established and spreading in Benin, Burundi, Ghana and Nigeria. Meanwhile, research on other potential natural enemies – including fungal pathogens – is continuing, in the hope of finding biocontrol agents best suited to the diverse environmental conditions within the cassava belt.



to the seed. The ants seek out seeds lying exposed on the soil surface and carry them into their underground nests, where they consume the elaiosomes but leave the seeds unharmed.

However, Argentine ants 'cheat' by eating the elaiosomes without taking the seeds underground, leaving them instead on the surface, where they are exposed to fire and to heavy predation by rodents. They also displace two species of native ants that are able to disperse large seeds by working cooperatively. Regeneration of large-seeded plants is therefore more likely to be impacted by fire and predation after invasion by Argentine ants, leading to a shift in the composition of fynbos plant communities. Furthermore, Argentine ants have been shown to deter some insect pollinators on protea flowers because of their aggressive behaviour.

Invasion by Argentine ants has resulted in equally dire consequences for ecosystems in other parts of the world. In California, for example, the ant thrives in temperate and damp coastal areas, and although only 2-3 mm in size, it

kills and displaces indigenous ants up to ten times larger. This appears to be one of the main reasons why the population of the coastal horned lizard has declined by 50% or more in areas where the ant has invaded. The lizard prefers to feed on larger indigenous ants, and tends to starve where these have been displaced by the smaller Argentine ant.

Invasion by Argentine ants also has various economic impacts. In orchards and vineyards, Argentine ants disperse and protect sap-sucking homopteran pests such as aphids and scales so that they can imbibe the sugar-rich honeydew secreted by these insects. By allowing homopteran infestations to increase, Argentine ants reduce the quality of crops and facilitate the transmission of diseases between plants.

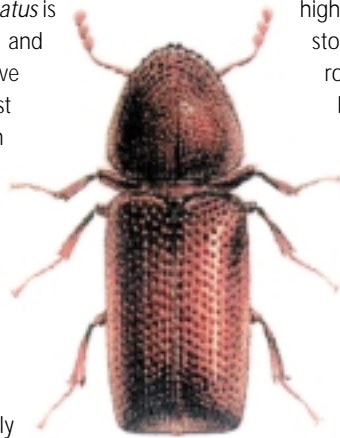
In addition, they have been known to cause losses by chewing holes in plastic drip irrigation pipes in orchards, by causing stress to brood chickens and killing hatchlings in poultry farms, by robbing bee hives of honey and preying on bees, and by contaminating food products.

## Larger grain borer

The larger grain borer *Prostephanus truncatus* is a destructive pest of farm-stored maize and dried cassava in sub-Saharan Africa. Native to South and Central America, it was first detected in Africa in the late 1970s in Tanzania, where it increased maize losses by as much as five times. In 1984 the first outbreak in West Africa occurred in Togo. The pest subsequently spread throughout East and West Africa and also began invading southward, reaching South Africa at the tip of the African continent in 1999.

The larger grain borer is particularly damaging to maize stored on the cob. The adult is a small, dark beetle, which either attacks maize in the field or after the crop is harvested. The beetle bores into the grain, feeding as it goes and leaving maize dust in its wake. Eggs are laid in side chambers excavated off the main tunnels, and after hatching the larvae feed on the surrounding maize dust.

The pest also attacks dried cassava – causing losses as



Larger grain borer

high as 70% after only four months of farm storage – as well as cereals, legumes, dried roots, tubers, peanuts, cocoa and coffee beans.

A biological control campaign was launched in 1991 with the introduction of the predatory beetle *Teretriosoma nigrescens*, but recent reports suggest it is not as effective as hoped. To date, pyrethroid insecticides – primarily Actellic Super Dust (ASD) containing permethrin and pirimiphos-methyl – have been the main line of defence against the larger grain borer. They necessitated a change in traditional storage practices, as efficient chemical control required that the maize be

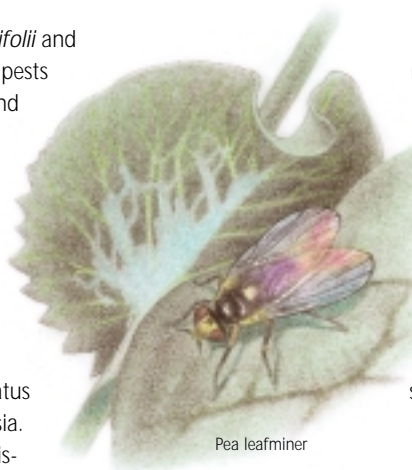
removed from the cob for treatment and storage. However, due to concerns about the safety of such insecticides, integrated pest management techniques and post-harvest management methods that are less of a risk to the environment and to human and animal health are now being explored.

## Leafminers

The leafminers *Liriomyza sativae*, *L. trifolii* and *L. huidobrensis* are small flies that are pests of a wide variety of vegetables and ornamentals. All three species are native to the Americas, but the global trade in horticultural products and large-scale production of ornamental flowers, particularly chrysanthemums, have allowed the species to expand their range worldwide.

In the late 1990s their pest status increased alarmingly in south-east Asia. This may be attributable to the indiscriminate use of insecticides in the past, which decimated natural enemies of the leafminers, precipitating destructive outbreaks.

The adult flies lay their eggs on the host plants and the larvae feed within the leaves. Although a single larva causes minimal damage, large populations destroy the leaves and affect the growth of plants. At high densities the pests significantly reduce crop yields; for example, in some areas of Indonesia, *L. huidobrensis* has been reported to have caused 100% yield loss in potato crops and up to 70% losses in other crops.



Pea leafminer

The leafminers have developed resistant to most insecticides, so Integrated Pest Management techniques are now being promoted in south-east Asia. These include biological control, cultivating resistant or tolerant cultivars of plants, using sticky yellow traps to capture the flies, and implementing management options and cultivation techniques that will discourage infestation by the pests. Selective insecticides should be used only as a last resort.



Celery leafminer